FROM: AFCESA/CES
139 Barnes Drive, Suite 1
Tyndall AFB FL 32403-5319

SUBJECT: **Engineering Technical Letter (ETL) 97-5: Proportioning Concrete Mixtures with Graded Aggregates for Rigid Airfield Pavements**

1. Purpose. This ETL provides(1) a method for selecting an aggregate grading to use in concrete mixtures for construction of Air Force rigid airfield pavements; and (2) an implementing construction specification. This guidance is nonmandatory.

2. Application: All Air Force organizations with pavement construction responsibility.

2.1. Authority: AFI 32-1028, *Standard Practice for Rigid Pavements* (replaces AFM 88-6CH6 and CH8).

2.2. Effective Date: Immediately.

2.3. Expiration: Five years from date of issue.

2.4. Ultimate Recipients:
- Air Force Base Civil Engineers, Red Horse Squadrons, and other units responsible for design, construction, maintenance, and repair of pavements.
- Corps of Engineers and Navy offices responsible for Air Force design and construction.

3. Referenced Publications: Refer to Attachment 1, Chapter 5 and Attachment 2, paragraph 1.1.

4. Procedure: Refer to Attachments 1 and 2.

5. Point of Contact: Mr. Jim Lafrenz, HQ AFCESA/CESC, DSN 523-6332, commercial (904) 283-6332 or INTERNET lafrenzj@afcesa.af.mil.

William G. Schauz, Colonel, USAF
Director of Technical Support

3 Atch
1. *Proportioning Concrete Mixture with Graded Aggregates - A Handbook for Rigid Airfield Pavements*
2. USAF 02515, *United States Air Force Guide Specification -- Military Airfield Construction*
3. Distribution List

APPROVED FOR PUBLIC RELEASE: DISTRIBUTION UNLIMITED

PROPORTIONING CONCRETE MIXTURES WITH GRADED AGGREGATES - A HANDBOOK FOR RIGID AIRFIELD PAVEMENTS

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Chapter 1

INTRODUCTION

1.1 Purpose.

1.1.1 The purpose of this handbook is to describe a method for selecting an aggregate grading for use in concrete mixtures which are to be used for the construction of Air Force rigid airfield pavement surface courses. A concrete mixture proportioning procedure is described which treats the combined graded aggregate as a single component of the mixture, rather than individual coarse, blend, and fine aggregate portions. The handbook describes guidelines for the selection of gradings, suitable for airfield pavements, that are compatible with workability requirements of concrete placements by mechanical means, either slipform or form and place, or by manual labor. The Air Force assumes that concrete durability is attained when the recommendations of this handbook are used to develop proportions for concrete mixtures.

1.2 Background.

1.2.1 The rigid pavements in the Air Force inventory are approaching the end of their calculated pavement life. Most of those pavements constructed in the late 1950’s and early 1960’s are being upgraded, because of mission realignment or changes, or replaced because they can no longer be effectively maintained. Reconstruction and rehabilitation programs started in the late 1980’s and continue today.

1.2.2 A significant number of those pavement systems which have been reconstructed experience early age distress syndrome. Even pavements constructed in the summer of 1995 must now be repaired during the summer of 1996. All of these failed pavements are structurally adequate and did meet quality control criteria of the specifications but, surface deterioration presents a hazard in the form of high probability for damage to high value aircraft. The early distress syndrome is of two general forms: spalling of the joint seal reservoir, and surface delamination or raveling. The surface distress usually occurs within one year of construction. The distress occurs in all environments, on projects accomplished by different contractors using different material sources, and on projects accomplished by different construction agents. There are numerous opinions on the nature of the surface deterioration, but the opinions do not include substantive recommendations for solving the problem. The problems are generally characterized by opinion as being the result of poor mixture design, poor workmanship, and poor quality control. A lack of educated and experienced construction inspectors is often cited as a contributory factor.

1.2.3 The United States Army Corps of Engineers, Waterways Experiment Station, (USAE/WES) concluded from their investigation that "the primary cause of the early-age spalling that recently has become relatively prevalent at military airfields appears to be primarily due to poor construction practices that may be caused or at least exacerbated by poor concrete mixture proportioning."[1] The Army Corps of Engineers further concluded that , "the engineering and construction profession should develop improved guidance on proportioning concrete mixtures for paving that must address workability of the mixture for slipformed paving and control of edge slump."

1.2.4 The Air Force Civil Engineering Support Agency, Directorate of Technical Support (HQ AFCESA/CES), looked at numerous projects which were accomplished since 1987. The study included both those pavements that have and those that have not exhibited early distress syndrome. A common factor among the projects studied are the combined grading of the aggregates and the high variability of aggregate gradations within specification imposed limits. Generally, projects constructed with aggregates that are near to being well graded perform better than those constructed with gap graded or poorly graded aggregates. The constructibility and uniformity of concrete mixtures with well graded aggregate is observed to contribute to better pavement performance. Exceptions to the general criteria were noted where significant daily material variations are observed.

1.2.5 The Air Force accepts the generalization that there are numerous potential problems in the concrete pavement industry. There are numerous questions which remain unanswered and the solutions to the numerous problems are beyond the scope and resources of a single entity. The Air Force is, therefore, electing to control the aggregate gradations and thereby, gain assurance that the concretes will be more uniform and more constructible. Solutions to other construction problems must be addressed with future programs.

1.2.6 The common procedure of industry-DoD for concrete mixture proportioning is the American Concrete Institute, *Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete* (ACI 211). Using this procedure can result in a concrete mixture with a poorly graded aggregate. It has been observed that concrete mixtures proportioned by ACI 211 tend to have fewer coarse aggregates and more fine aggregate. The

[1] Rollings, Raymond, S., "Joint Spalling in Newly Constructed Concrete Pavements, " ASCE, J. Performance of Constructed Facilities, 1996.

footnote recommendations within ACI 211 for pavement quality concrete is generalized, and for most projects, the footnotes of ACI 211 are ignored. Mixtures proportioned by using ACI 211 tend to be gap graded, of high sand content, and prone to segregation when subject to vibration. This can result in pavement placements which have problems with edge slump, consolidation, and finishing. This does not mean that a pavement with gap graded aggregates cannot be placed and finished.

1.3 Scope.

1.3.1 This handbook is intended to serve as a guide for selecting aggregates, and concrete proportions, that will meet the expectations of the Air Force. It is important for the user, either the person doing concrete mixture proportioning, or the one doing an evaluation of a proportioning study, to understand that this handbook is written to allow for the use of materials available in the locale of the project. The person selecting the aggregate portions may procure materials using ASTM references, local DOT references, or other identification. The aggregate, as a combined blend, is the single interest of the Air Force. Quality control procedures must assure that the combined grading remains within the band selected by the person doing the mixture proportioning. This handbook must be used with the *USAF Guide Specification 02515, Military Airfield Construction, Rigid Concrete Pavement for Airfields*.

1.3.2 The person purchasing raw materials must establish the limits of the grading selected for each material to be used in a certain combined grading; i.e., stockpile control. This should be interpreted to mean, that the person who purchases an aggregate component should specify not only the standard stone size, but also the gradation and tolerance for variance within that generic size limit.

1.3.3 The guidelines in this handbook are based upon empirical relationships and observations. Each aggregate (coarse, blend, or fine) must be viewed as a contributor to the workability, the uniformity, and the suitability of the concrete mixture. The size of the aggregate is only one indicator of expected performance. Aggregate shape, texture, angularity, etc., must also be considered in proportioning a mixture that will respond positively to the method of placement and finishing. Each Air Force base should establish a catalog of aggregate performance and combined gradings that result in successful pavement placement. The catalog is then used as a judge for future construction activities. In the absence of that catalog, this handbook is to be used as a guide to develop a concrete mixture that is assumed to satisfy the expectations of the Air Force.

1.3.4 Those individuals involved in the evaluation of concrete mixture proportioning studies should expect that not all proposed mixtures will meet all requirements. Judgment is necessary to assure that the best possible product can be obtained from the resource limitations of the project. There are no cookbook solutions to a concrete mixture proportioning study. This does not mean that substandard products will be allowed. It does mean that aggregate blending may be necessary using materials that, individually, would not satisfy the grading limits of standard references. Under no conditions will aggregate quality be sacrificed to attain the appropriate grading, or to allow use of local materials. Where variation from the recommended practice of this handbook is encountered, the person evaluating the mixture should seek technical assistance through the respective major command.

Chapter 2

MATERIALS

2.1 Materials used for the concrete mixture include: coarse aggregate, blending aggregate, fine aggregate, cement, water, mineral admixtures, chemical admixtures, and air content.

2.2 Coarse Aggregate.

2.2.1 Coarse aggregate consists of one or a combination of gravel or crushed aggregate with particles being retained on and above the No. 4 ASTM standard sieve.

2.2.2 **Composition.**

2.2.2.1 Coarse aggregate consists of gravel, crushed gravel, crushed stone or a combination thereof.

2.2.3 **Quality.**

2.2.3.1 The aggregates used should meet the quality requirements of the specification. The specifier of the aggregate should designate the class of coarse aggregate to be used in the project based on factors of exposure. Class designations include: mild exposure, where concrete is rarely exposed to freezing in the presence of moisture; moderate exposure, where concrete should not be continually exposed to freezing and thawing in the presence of moisture or to deicing chemicals; and severe exposure, where concrete may become saturated with moisture prior to repeated freezing and thawing and be exposed to deicing chemicals or other aggressive agents.[2] If not familiar with the geographical locations corresponding the above exposure conditions, refer to ASTM C 33, Figure 1, "Location of Weathering Regions."

2.2.4 **Particle Shape.**

2.2.4.1 The quantity of flat and elongated particles in any size group should not exceed 20 percent, by mass, as determined by CRD-C 119, "Flat and Elongated Particles in Coarse Aggregate." A flat particle is defined as one with a ratio of width to thickness greater than three. An elongated particle is one having a ratio of length to width greater than three. The water required to produce a given workability should increase as the number of flat, elongated and rough textured particles increases.

2.2.5 **Maximum Size.**

2.2.5.1 The nominal maximum aggregate size is defined as the smallest sieve opening through which the entire amount of the aggregate is permitted to pass. The nominal maximum sieve sizes used for airfield pavements are 37.5mm, 25mm, and 19mm. The nominal maximum aggregate

[2] American Concrete Institute, ACI 211, "Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete."

size for pavements constructed in geographical locations where D-cracking aggregates are encountered should be 19mm.

2.2.6 **Grading.**

2.2.6.1 Aggregates should be sampled according to ASTM D 75, "Standard Practice for Sampling Aggregates," prior to performing a sieve analysis according to ASTM C 136, "Sieve Analysis of Fine and Coarse Aggregates." Sieves used for the analysis include 50mm, 37.5mm, 25mm, 19mm, 12.5mm, 9.5mm, No. 4, and No. 8.

2.3 Blending Sizes.

2.3.1 Blending sizes are immediate size particles normally passing the 9.5mm sieve and retained on the No. 50 sieve.

2.3.2 **Composition.**

2.3.2.1 Blending sizes should be materials of either natural deposits, manufactured products, or combinations thereof.

2.3.3 **Quality.**

2.3.3.1 Blending sizes should meet the quality fine aggregate requirements of ASTM C 33 and/or the specifications, whichever is more stringent.

2.3.4 **Particle Shape.**

2.3.4.1 The particles should be generally cubical in shape without the presence of elongated or slivered materials.

2.4 Fine Aggregate.

2.4.1 Fine aggregate is defined as clean granular materials, generally consisting of natural sand or crushed stone, with most particles passing the No. 4 ASTM standard sieve.

2.4.2 **Composition.**

2.4.2.1 Fine aggregate consists of natural sand, manufactured sand, or a combination thereof.

2.4.3 **Quality.**

2.4.3.1 The amount of deleterious substances in the fine aggregate should not exceed the limits given in ASTM C 33, Table 1 and/or the specifications, whichever is more stringent

2.4.4 **Grading.**

2.4.4.1 The fine aggregate, as delivered to the stockpile, should be proportional to the limits of ASTM C 33. The maximum limitation of ASTM C 33 for fineness modulus of 3.1 is NOT applicable for fine aggregate being used for slipform paving and form-in-place applications. The USAF minimum limitation for fineness modulus is 2.3. An example of a fineness modulus calculation is provided in Table 3.1. The fine aggregate should not have more than 45 percent passing any sieve and retained on the next consecutive sieve. Fine aggregates should be sampled according to ASTM D 75 prior to performing a sieve analysis according to ASTM C 136. Sieves used for the analysis include 9.5mm, No. 4, No. 8, No. 16, No. 30, No. 50, and No. 100.

2.5 Cement.

2.5.1 The Portland cement should conform to ASTM C 150, "Standard Specification for Portland Cement." The type of the cement to be used is selected by the contractor. The tricalcium silicate content of the cement should be limited to a maximum of 55 percent, and the content of alkalies calculated as (Na_2O + 0.6 K_2O) should be limited to 0.75 percent maximum.

2.5.2 Types IA, IIA, and IIIA, which are Portland cements containing interground additions of air-entraining agent should not be used for airfield pavement mix designs. Blended cements consisting of two or more inorganic constituents that contribute to the strength-gaining properties of the cement, that meet the performance requirements of ASTM C 1157M, "Standard Performance Specification for Blended Hydraulic Cement," will be considered only on a case by case basis.

2.5.3 **Cement Source.**

2.5.3.1 Since many foreign sources of cement ASTM 1157 are being used today for pavement projects, the purchaser should request that the cement be sampled and tested to verify compliance according to ASTM C 183, "Standard Methods for Sampling and Acceptance of Hydraulic Cement," and ASTM C 1157M, "Standard Performance Specification for Blended Hydraulic Cement."

2.5.4 **Cement Content.**

2.5.4.1 The minimum portland cement content should be 335 kilograms per cubic meter (564 pcy) of concrete, when using <u>only</u> portland cement as the cementitious component of the concrete mixture. When pozzalanic materials such as fly ash are used in concrete, the minimum amount of portland cement should be 307 kilograms per cubic meter (517 pcy) of concrete. The amount of cementitious material is determined by the amount of portland cement plus the amount of fly ash.

2.6 Water.

2.6.1 Water for washing aggregates and for mixing concrete should be free from harmful amounts of oil, acid, salt, alkali, organic matter, or other deleterious substances. The properties of the water should exceed the minimum requirements given in CRD C-400, “Water for Use in Mixing or Curing Concrete.”

2.6.2 **Water Cementitious Ratio.**

2.6.2.1 The water cementitious material ratio is defined as the mass of water (W) divided by the combined mass of cement (C) plus the mass of fly ash (P) as given in the following equation (W/C+P). This ratio should not exceed 0.45. The water cementitious material ratio should represent the minumum amount of water required to obtain a given workability for any given aggregate grading.

2.7 Mineral Admixtures (Fly Ash).

2.7.1 Class F and Class C fly ashes, as defined by ASTM C 618, “Fly Ash and Raw or Natural Pozzolan for Use as a Mineral Admixture in Portland Cement Concrete,” are commonly used as pozzolanic admixtures for concrete. The mass of fly ash used in the mix should not be less than 15 percent nor more than 25 percent of the total cementitious material; that is, the ratio of the mass of fly ash divided by the combined mass of fly ash and the mass of Portland cement should not be less than 15 percent nor more than 25 percent of the total cementitious material.

2.7.2 When using Class C fly ash, a chemical analysis should be conducted to evaluate the solubility parameters of the aluminum (Al_2O_3) and the sulfur (SO_3). One recommendation is “solubility of the SO_3 and Al_2O_3 shall be a minimum of 90 percent of the total available.”[3]

2.8 Chemical Admixtures.

2.8.1 Chemical admixtures are those ingredients in concrete other than portland cement, mineral admixtures, water, or aggregates that are included in the mixture prior to placement. Chemical admixtures are classified as: air-entraining, set-retarding, set-accelerating, water reducing, and high-range water-reducing. Specifications for chemical admixtures are given in ASTM C 494, “Chemical Admixtures for Concrete.”

2.8.2 Admixtures used in the mix design of rigid airfield pavements must be compatible with other mixture components and are required to be certified as being so by the manufacturer and/or its representative for a given concrete mixture, and can in no way impair the quality of the mixture by affecting the workability, placeability, finishibility, and strength.

[3] Gress, D.L. “Recommendations for Mitigating Early Distress in Concrete Pavements,” Presented to the American Concrete Pavement Association, Durability Committee, June 12, 1996.

2.8.3 Air-entraining admixtures are used to purposely entrain microscopic air bubbles into concrete. Air entrainment should improve the durability of the concrete exposed to cycles of freezing and thawing. The type of admixture and dosage rate should have an effect on workability and strength. Air entrainment should be used in both severe and moderate weathering regions as described in ASTM C 33.

2.8.4 Set-retarding admixtures are used to retard the time of setting of concrete. These admixtures are used during hot weather concreting; that is, when fresh concrete temperatures exceed 29 °C or when concrete is being delivered over considerable distances.

2.8.5 Set-accelerating admixtures are used to accelerate the strength development of concrete at an early age. Calcium chloride is not recommended by the USAF as an accelerator for rigid airfield pavements. Only non-chloride set-accelerating admixtures meeting ASTM C 494 should be used.

2.8.6 Water-reducing admixtures are used to reduce the quantity of mixing water required to produce concrete of a certain workability. The use of these admixtures can allow one to reduce the water cement ratio, thereby increasing the strength of the concrete, without reducing the workability, or one can increase the workability of the concrete mixture without increasing the water cement ratio, thereby maintaining the strength of the mix. Ordinary water reducers reduce the water content by approximately 5 to 10 percent.

2.8.7 High-range water-reducing admixtures are described in ASTM C 1017, "Chemical Admixtures for Use in Producing Flowing Concrete," and C 494-86 Types F and G specifications. High-range water-reducers reduce water content by 12 percent to 30 percent. High-range water-reducers are more effective in reducing the water/cement ratio for a given concrete. Yet, the effect is usually short-lived, and loss of workability often occurs within 30 to 60 minutes. Compatibility with other admixtures, particularly air-entraining agents, must be verified, since they can affect the amount and size of the entrained air bubbles significantly.

2.9 Target Air Content.

2.9.1 The air content, by volume, should be selected based upon Table 2.1, "Target Air Content for Airfield Pavement Concrete." The air content should be determined from concrete samples selected from in front of the paver. Allowance for loss of air due to mixing, transportation, and placement must be provided. The exposure definitions provided in Portland Cement Association (PCA) Engineering Bulletin, "Design and Control of Concrete Mixtures," apply.

TABLE 2.1 Target Air Content for Airfield Pavement Concrete

TARGET AIR CONTENT (PERCENT BY VOLUME)			
Nominal Maximum Aggregate Size (mm)	**Severe Exposure**	**Moderate Exposure**	**Mild Exposure**
37.5	5 1/2	4 1/2	2 1/2
25	6	4 1/2	3
19	6	5	3 1/2

The air content of the delivered concrete to be within -1 to +2 percentage points of the table target values.[4]

[4] "Design and Control of Concrete Mixtures," Engineering Bulletin EB001.13T, Portland Cement Association

Chapter 3

COMBINED AGGREGATE GRADING

3.1 The concrete mixture should be proportioned so that the requirements for workability and finishibility are satisfied. The mixture should also be proportioned as a well-graded combined aggregate, and the minimum requirements for air content and water cementitious ratio are not exceeded.

3.2 Percent Combined Aggregate Retained Graph.

3.2.1 Grading reports should include the following sieve sizes: sieves used for the analysis include 50mm, 37.5mm, 25mm, 19mm, 12.5mm, 9.5mm, No. 4, No. 8, No. 16, No. 30, No. 50, and No. 100. The proportions selected for the combined gradation should be plotted on a graph as the percentage retained for each reporting sieve size (y-axis) versus the considered sieve size (x-axis). The plot of the graph should be a line showing a relatively smooth transition between coarse and fine aggregate. The maximum and minimum percent retained limits, represented by the dotted lines in Figure 3.1, are to be taken only as a guide, and the plot should not have a significant valley or peak between the 9.5mm sieve size and the finest reporting sieve size. An example of the percent aggregate retained graph, including a satisfactory and unsatisfactory combined aggregate gradation plot, is shown in Figure 3.1.

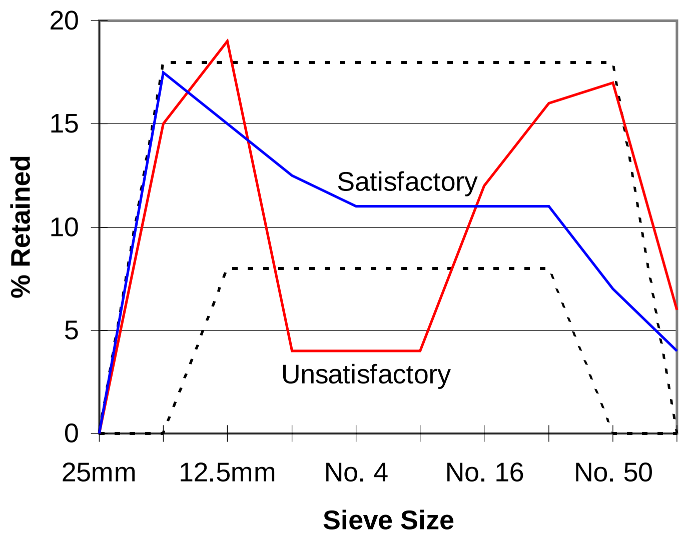


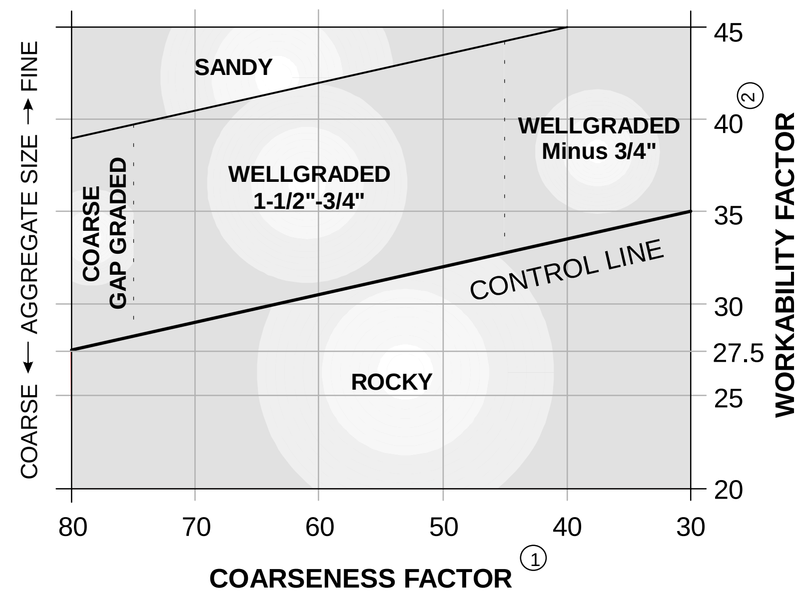
Figure 3.1 Percent Combined Aggregate Retained

3.3 Coarseness Factor/Workability Factor.

3.3.1 The combined aggregate grading should be used to calculate a coarseness factor and a workability factor. The coarseness factor for a particular combined aggregate gradation is determined by dividing the amount retained above the 9.5mm sieve by the amount retained above the No. 8 sieve, and multiplying the ratio by 100.[5]

3.3.2 The workability factor is the percentage of combined aggregate finer than the No. 8 sieve.[6] This factor can simply be determined by using the percentage passing the No. 8 sieve, from the combined aggregate sieve analysis. The workability factor is to be increased by 2.5 percent for each 56 kg per cubic meter (94 pcy) of cementitious material used in excess of the baseline amount of 335 kg per cubic meter (564 pcy) of cementitious material. The workability factor is only adjusted upwards because the minimum amount of cementitious material for rigid airfield pavement mix designs is 335 kg/ cubic meter (564 pcy) of cementitious material.

3.3.3 The coarseness and workability factors are plotted on a chart similar to that shown in Figure 3.2. The coarseness factor should not be greater than 80 nor less than 30. The plot of the workability factor and the coarseness factor is a single point which is to be above the control line and within the workability box, shown in Figure 3.2.



NOTES:

1 **COARSENESS FACTOR =** $\frac{\text{\% RETAINED ABOVE 9.5mm SIEVE}}{\text{\% RETAINED ABOVE \#8 SIEVE}} \times 100$

2 **WORKABILITY FACTOR =** % PASSING #8

Figure 3.2 Aggregate Proportioning Guide

[5] Shilstone, James M. Sr., "Concrete Mixture Optimization," ACI Concrete International, June, 1990.

[6] IBID

3.4 Aggregate Proportioning Guide.

3.4.1 When a combined aggregate grading appears to meet the criteria of the percent retained graphic, it is then necessary to assess where in the workability box is best suited to the method of placement. In theory, it would be assumed that the best combined aggregate gradations for slipform paving would be at the lower left of the box near the control line -- Area A in Figure 3.3. An aggregate grading at the lower right corner of the workability box should be suitable for use with form and place mechanical pavers -- Area B in Figure 3.3. This assumes that smaller aggregate sizes are needed to move the coarseness factor to a lower number and increase workability. Additionally, combined aggregate selections at the top of the box would be suitable for hand placement -- Area C in Figure 3.3.

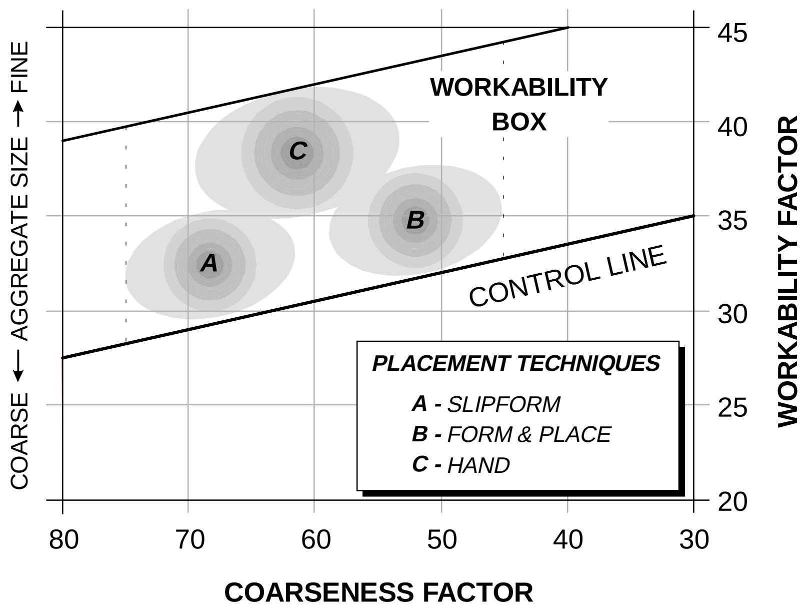


Figure 3.3 Workability Box Within Aggregate Proportioning Guide

3.4.2 One should not expect the above to be exact because the aggregate proportioning guide for grading does not take other “workability” factors into account. The shape of the fine aggregate particles will affect workability, but this is not reflected in the grading. Rounded coarse aggregate particles would also affect workability, but would not be reflected in the grading. Increasing or decreasing the entrained air content will directly affect the workability. Air content is not even considered in the aggregate proportioning guide. Chemical admixtures are used to adjust the workability of the mixture and should not be neglected in the final selection of a concrete mixture for constructibility.

3.4.3 The aggregate proportioning guide should be used just as the title suggests, as a guide, and not as a rule. It is necessary that the person doing the mixture proportioning be familiar with the method of placement and the characteristics of the mixture that are best suited to that method.

In a similar fashion, the person evaluating the mixture proportioning study must balance the data presented and the results of previous paving projects. The final test, for both the contractor and the owner, are the characteristics and the response of the mixture to the method of placement as observed at a test strip placement.

3.4.4 A very important consideration in selecting the final design aggregate grading, using the aggregate proportioning guide, is the location of the design grading relative to the expected daily variance of the concrete mixture materials. Changes in coarse, blend, and fine aggregate gradings could place the plot outside of the workability box, as illustrated in Figure 3.4. A normal variance of about 5 percent on the coarseness factor and about 3 percent on the workability factor should be considered in the final selection of an aggregate blend. Therefore, Design A would be a better choice than Design B, considering the daily variance.

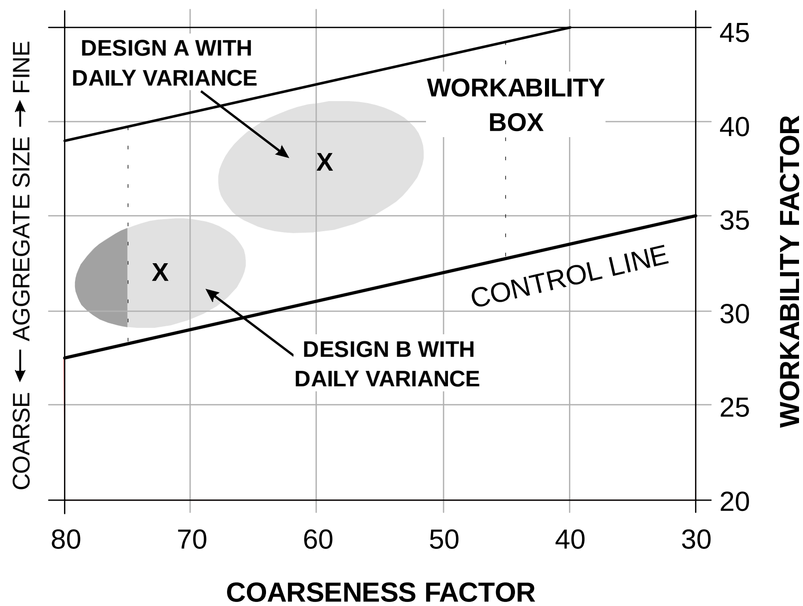


Figure 3.4 Daily Variance Within Workability Box for Aggregate Proportioning

3.5 Interpretation of Graphical Procedures.

3.5.1 Two questions will plague that engineer accustomed to using mathematical bounds on material variability for materials acceptance or rejection. What is considered “significant” when judging the retained aggregate on successive sieves? Where in the workability box are the limits for different methods of pavement placement? The answer to those questions may be answered only after a catalog of combined aggregate gradings is established for each locale. Each locale will have different answers because of the variation in aggregate gradings, particle shape, texture and performance. Variation can also be expected within a locale because of quarry or pit source differences.

3.5.2 **Percent Combined Aggregate Retained.**

3.5.2.1 A generic judgment can be made about the expected performance of concrete pavements based upon known material characterizations. The first involves selecting aggregate grading based upon retainage, by mass, on successive sieve sizes.

3.5.2.2 The optimum solution to the well graded aggregate criteria is nominally the classical "haystack," Figure 3.5. The "haystack" grading is recommended by The American Concrete Pavement Association (ACPA)[7] for Fast Track paving because it provides for reduced water demand, increased durability, and better workability. The classic "haystack" is almost impossible to produce from most local materials at any economic advantage. The question then becomes how close do I have to be to the "haystack" grading configuration?

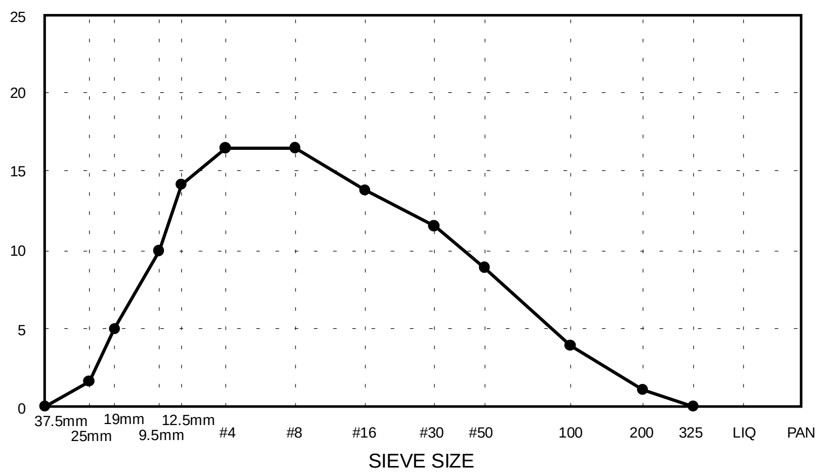


Figure 3.5 "Haystack" Particle Distribution for a Uniformly Graded Mixture

[7] American Concrete Pavement Association, ACPA, Technical Bulletin TB004P, "Fast Track Concrete Pavements."

3.5.2.3 By using the percentage retained method of graphing, you may visualize the approximation of the combined grading to the "haystack" shape. Most combined gradings will plot as a series of peaks and valleys as illustrated in Example A, Figure 3.6. It is desired that there be a gradual increase in material retained on each sieve to the stone sizes larger than 12.5mm and then have a gradual tapering of the curve from the 9.5mm size to the lowest sieve size. A general rule of thumb is to keep the material retained on each sieve to less than 18 percent but more than 8 percent. An acceptable curve will have peaks prior to the 9.5mm size and then a uniform transition to the lowest size materials. In Example A of Figure 3.6, the small peak at the No. 4 sieve size would be acceptable since the valley following the No. 4 is about the same percentage from the deviation of a straight line between the 9.5mm size and the No. 16 sieve size.

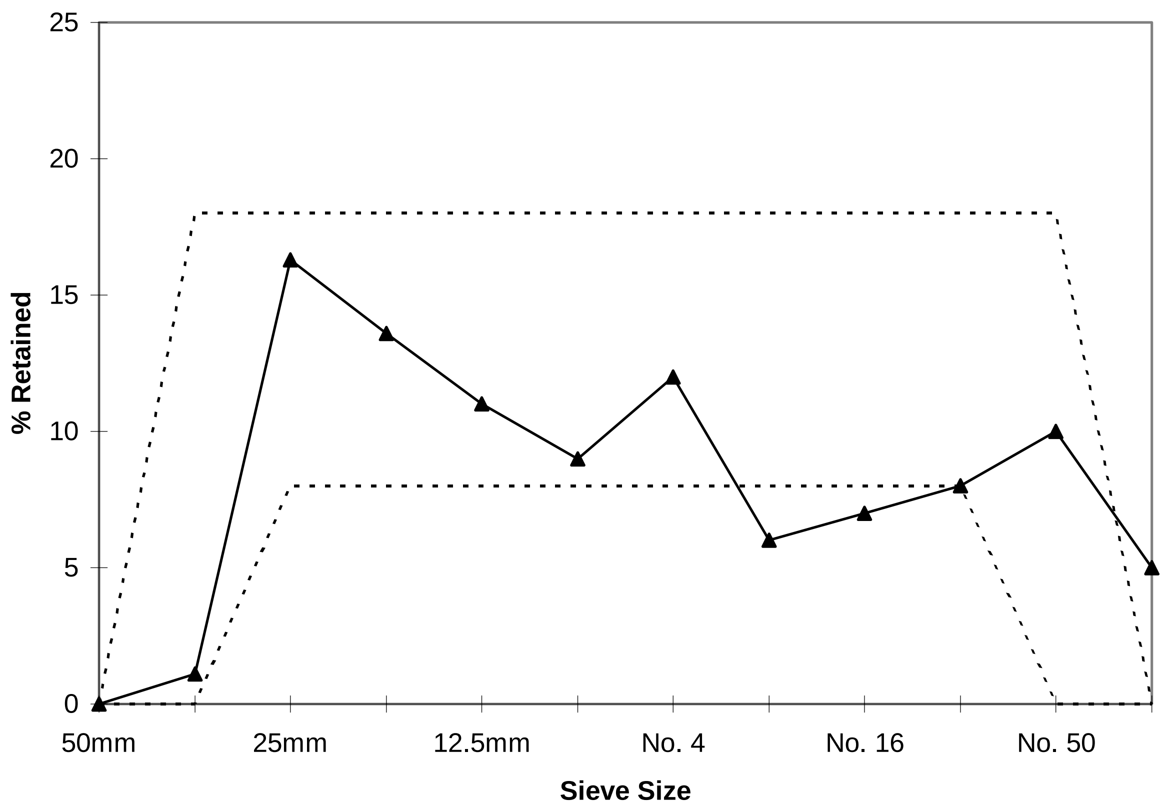


Figure 3.6 Example A

3.5.2.4 A typical distribution is a peak at the 12.5mm stone size and a significant reduction (valley) in the materials from the 9.5mm size to the Number 50 sieve size as shown in Example B, Figure 3.7. Most aggregates used for concrete mixtures are deficient in the 9.5mm to the No. 30 sieve sizes; therefore, most combined gradings will have a gap in the blend size particles. The peak at the Number 50 sieve size is there because the Number 50 sieve size is the size of most natural sand particles. Typically, you would classify this grading as being gap-graded. This grading is not acceptable because there is a significant valley, more than two adjacent sieve sizes, between two peaks. Additionally, the peaks for the larger stone sizes exceed the 18 percent guidelines for two successive sieve sizes. To create a uniform grading for the latter, it is necessary to add a blend material that would have the missing intermediate size (blend size) particles.

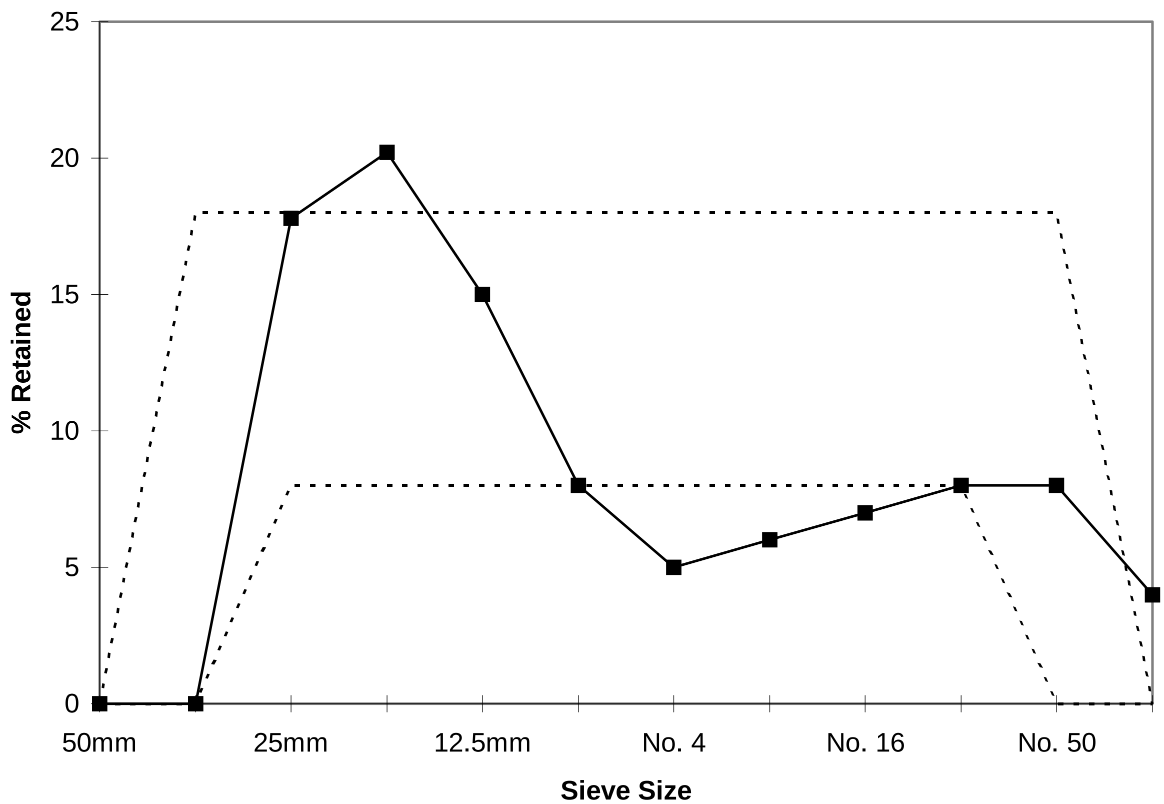


Figure 3.7 Example B

3.5.2.5 An example of an unacceptable combined grading that incorporates the necessary blending sizes is shown in Example C, Figure 3.8. For this material, the peak in the curve occurs at and adjacent to the top size of the aggregate; i.e., the first sieve size which retains material. The adjacent sieve size is also at the peak. The result is that there is a large quantity, by weight, of large stone sizes. There is little volume left to provide for the blend and the fine aggregate sizes. The resulting combined aggregate grading will have a "plums in the pudding" effect. These mixtures tend to segregate upon vibration and finish poorly because of excessive voids which must be filled with mortar.

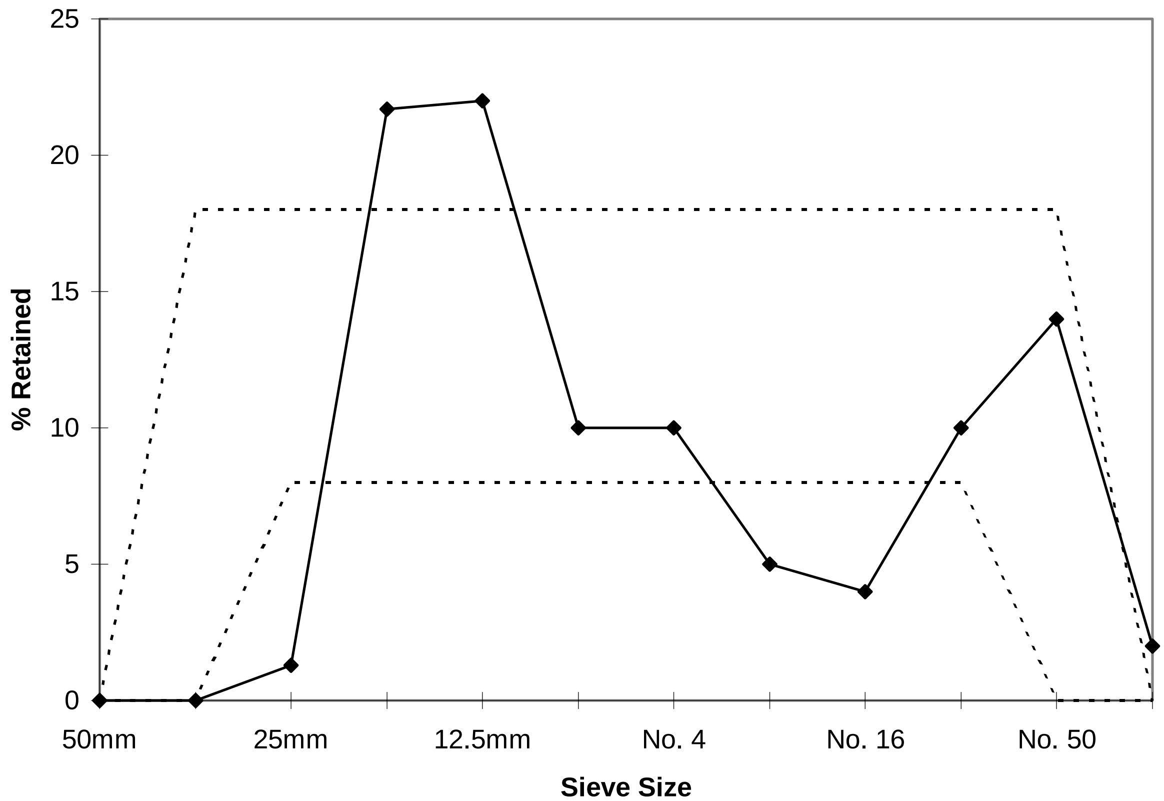


Figure 3.8 Example C

3.5.2.6 When there remains doubts about the suitability of a certain combined grading, it is recommended that the grading be plotted on a 0.45 power curve, as shown in Figure 3.9. The grading should wander along the line associated with the top aggregate size. The meander across and back of the top size line indicates where the material is gap graded. To ascertain what is a reasonable amount of gap grading, the curve should be examined for the maximum departure from the maximum density line (top size line).

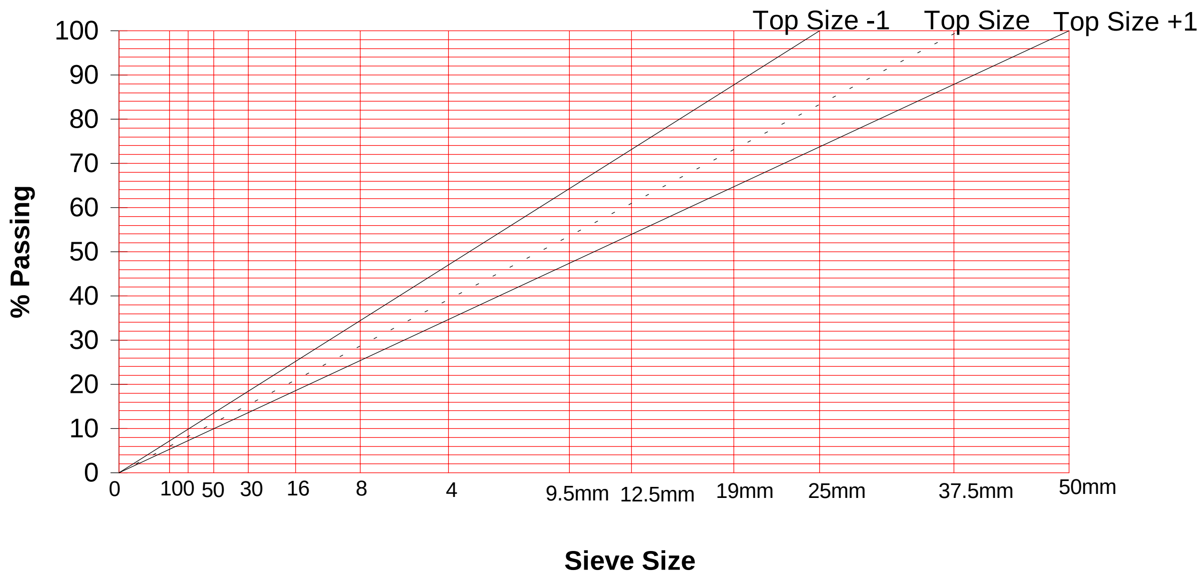


Figure 3.9 The 0.45 Power Grading Chart

3.5.2.7 With the combined grading of the certain aggregate plotted on the 0.45 chart, draw maximum density lines for the first size of material larger and the first size of material smaller than the target gradation, Figure 3.9. If the combined aggregate grading curve crosses the lines drawn on either side of the top size line, it can be generally assumed that the material has excessive amounts of gap grading and is not an acceptable grading for paving, as shown for Example C plotted in Figure 3.10.

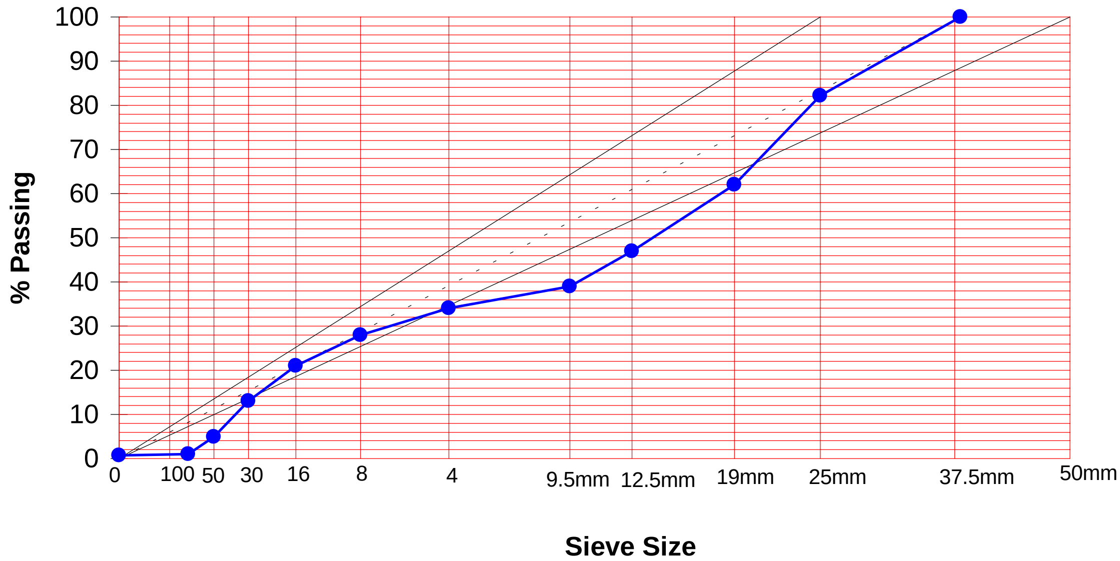


Figure 3.10 Example C Plotted on 0.45 Power Chart

3.6 Fineness Modulus of the Fine Aggregate.

3.6.1 The fine aggregate, as delivered to the stockpile, should be graded within the limits of ASTM C 33 (see Figure 3.11). The maximum limitation of ASTM C 33 for fineness modulus of 3.1 is NOT applicable for fine aggregate being used for conventional paving applications. The USAF minimum limitation for fineness modulus is 2.35, while the minimum limitation for fineness modulus according to ASTM C33 is 2.15, as shown in Figure 3.3. The fine aggregate should be well-graded and correspond to the general shape of the grading curves shown in Figure 3.5. For concrete placed by mechanical means, the fine aggregate should have a minimum percent passing the No. 50 and No. 100 sieves of 5 and 0, respectively. The fineness modulus is calculated by adding the total percentage of material in the fine aggregate sample that is coarser than each of the following sieves, and dividing the sum by 100. Sieves used for the analysis include 9.5mm, No. 4, No. 8, No. 16, No. 30, No. 50, and No. 100. Fine aggregate should be sampled according to ASTM D 75 prior to performing a sieve analysis according to ASTM C 136.

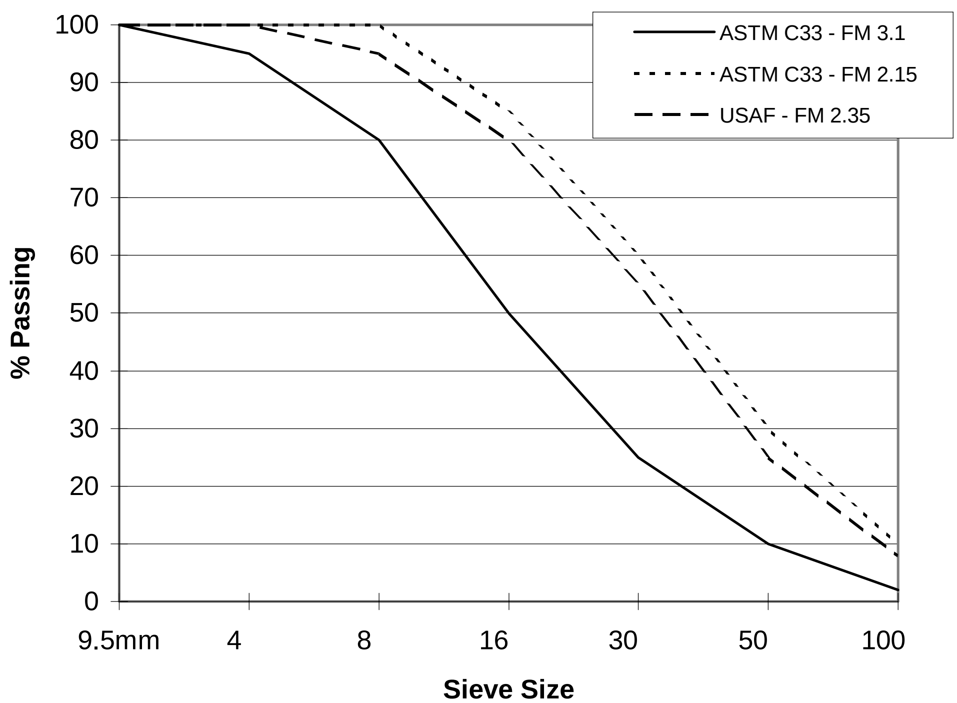


Figure 3.11 Fine Aggregate Grading Limits

3.6.2 An example of the fineness modulus calculation is given in Table 3.1. The percent passing each of the specific sieves, 9.5mm, No. 4, No. 8, No. 16, No. 30, No. 50, and No. 100, is tabulated. The total amount of material coarser than each of the following sieves is tabulated next. The sum of the percent cumulatively retained is determined; i.e., 300; and the sum is then divided by 100 resulting in a fineness modulus or FM of 3.00 in this example.

TABLE 3.1 Fineness Modulus Calculation

Sieve Size	% Passing	% Cumulatively Retained
	ASTM C-33	ASTM C 33
9.5mm	100	0.00
4	95	5.00
8	80	20.00
16	60	40.00
30	40	60.00
50	20	80.00
100	5	95
		300.00
		FM = 3.00

Chapter 4

MIX PROPORTIONING

4.1 The procedure for selecting mixture proportions given in this section is applicable to normal weight concrete to be placed by slipform or form-in-place machine paving techniques. Estimating the required batch amounts for the concrete constituents can be accomplished using the following steps.

4.2 Estimation of Workability.

4.2.1 For the purposes of estimating workability, one method commonly used is the measure of slump as determined by ASTM C 143, "Standard Test Method for Slump of Hydraulic Cement Concrete." The workability of the mixture should be dictated by the type of field placement method proposed by the contractor. Mix workability should have a maximum slump of 25mm for slipform paving and a maximum slump of 75mm for form-in-place methods of field placement.

4.3 Nominal Maximum Size of Coarse Aggregate.

4.3.1 The nominal maximum size of coarse aggregate should be determined by the contractor based on the following guidelines: The nominal maximum size used for airfield pavements should be either 37.5mm, 25mm, or 19mm; and in geographical areas where 'D' cracking is known to be a problem, the nominal maximum size of coarse aggregate should be 19mm.

4.4 Estimation of Cementitious Material Content.

4.4.1 The minimum cementitious materials content should not be less than 335 kilograms per cubic meter (564 pcy) of concrete, and the minimum Portland cement content should not be less than 307 kilograms per cubic meter (517 pcy) of concrete when fly ash is incorporated into the mixture. The amount of cementitious material is determined by the amount of portland cement plus the amount of fly ash. When Class F or C fly ash is utilized, as designated by ASTM C 618, the mass of fly ash used in the mix should not be less than 15 percent nor more than 25 percent of the total cementitious material. That is, the ratio of the mass of fly ash divided by the combined mass of fly ash and the mass of Portland cement should not be less than 15 percent nor more than 25 percent of the total cementitious material.

4.4.2 When using the minimum amount of flyash, 15 percent, and using the minimum amount of portland cement described in Section II-D, 307 kilograms per cubic meter (517 pcy), the following applies:

4.4.2.1 M(fa)/[M(fa) + M(pc)] = 0.15

4.4.2.2 M(fa)/[M(fa) + 307 kg/m^3]= 0.15

4.4.2.3 M(fa) = 54 kg/m^3 (91 pcy)

4.4.2.4 M(cementitious material) = 307 kg/m^3 + 54 kg/m^3 =361 kg/m^3 (608 pcy)

4.4.3 When using the maximum amount of flyash, 25 percent, and using the minimum amount of portland cement described in Chapter 2, paragraph 2.5.4.1, of 307 kilograms per cubic meter (517 pcy), the following applies:

4.4.3.1 M(fa)/[M(fa) + M(pc)] = 0.25

4.4.3.2 M(fa)/[M(fa) + 307 kg/m^3] = 0.25

4.4.3.3 M(fa) = 102 kg/m^3 (172 pcy)

4.4.3.4 M(cementitious material) = 307 kg/m^3 + 102 kg/m^3 = 409 kg/m^3 (689 pcy)

4.5 Estimation of Air Content.

4.5.1 Determine the air content for the proposed mix from Table 4.1, based on the nominal maximum size aggregate and the type of exposure as indicated by weathering regions associated with the project location. The exposure definitions provided in Portland Cement Association (PCA) Engineering Bulletin, "Design and Control of Concrete Mixtures," apply.

TABLE 4.1. Target Air Content for Airfield Pavement Concrete

TARGET AIR CONTENT (PERCENT BY VOLUME)			
Nominal Maximum Aggregate Size (mm)	**Severe Exposure**	**Moderate Exposure**	**Mild Exposure**
37.5mm	5 1/2	4 1/2	2 1/2
25mm	6	4 1/2	3
19mm	6	5	3 1/2

The air content of the delivered concrete to be within -1 to +2 percentage points of the table target values.[8]

[8] "Design and Control of Concrete Mixtures," Engineering Bulletin EB001.13T, Portland Cement Association

4.6 Coarse and Fine Aggregate as Single Aggregate Blend.

4.6.1 The amount of coarse aggregate, blended aggregate, and fine aggregate should be treated as a single component of the mixture and determined from the limits set forth in the Combined Aggregate Proportioning Guide and the Percent Combined Aggregate Retained Graph, Figures 3.1 and 3.2, respectively. Aggregate properties are determined by the contractor and should include dry-rodded unit weight, bulk specific gravity (saturated surface-dry), and percent absorption, for the coarse aggregate fraction. For the fine aggregate fraction, properties provided by the contractor should include bulk specific gravity (saturated surface-dry), percent absorption, and fineness modulus.

4.7 Weighted Average Specific Gravity of Aggregate Blend.

4.7.1 Calculate the weighted average specific gravity (ssd) for the aggregate blend (coarse, blended and fine aggregate). The weighted average specific gravity should be used to calculate the estimated unit weight of the fresh concrete mixture. The weighted average specific gravity (ssd) of the aggregate blend is equal to the sum of the individual percents of aggregates used in the blend multiplied by their individual saturated surface-dry bulk specific gravity values.

4.7.2 $S_{wa(ssd)} = [\%CA*S_{ca(ssd)} + \%BA*S_{ba(ssd)} + \%FA*S_{fa(ssd)}]/100$

where:

4.7.2.1 $S_{wa(ssd)}$ - weighted average bulk specific gravity (ssd) of the aggregate blend.

4.7.2.2 %CA - mass percent of the aggregate corresponding to the coarse aggregate fraction.

4.7.2.3 $S_{ca(ssd)}$ - bulk specific gravity (ssd) of the coarse aggregate fraction.

4.7.2.4 %BA - mass percent of the aggregate blend corresponding to the blending aggregate fraction.

4.7.2.5 $S_{ba(ssd)}$ - bulk specific gravity (ssd) of the blending aggregate fraction.

4.7.2.6 %FA - mass percent of the aggregate corresponding to the fine aggregate fraction.

4.7.2.7 $S_{fa(ssd)}$ - bulk specific gravity (ssd) of the fine aggregate fraction.

4.8 Estimation of Water Cementitious Material Ratio.

4.8.1 Determine the water cementitious material ratio to produce a workability as determined in Step 1, not to exceed a maximum value of 0.45. This maximum corresponds to both water cement ratio, when using only portland cement, and water cementitious ratio when using portland cement plus fly ash. The optimum water cementitious material ratio should represent the minumum amount of water required to obtain a given workability for any given aggregate grading.

4.9 Fresh Concrete Unit Mass in Kilograms per Cubic Meter.

4.9.1 Calculate the wet density of the concrete mix per cubic yard by using the following formula as described in ACI 211.1, "Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete." This calculation is used to estimate the mass of combined aggregate required for the concrete mixture.

4.9.2 $U = 10 * S_{wa} * (100 - A) + C * (1 - S_{wa} / S_c) - W * (S_{wa} - 1)$

where:

4.9.2.1 U = the mass of fresh concrete per cubic meter, in kilograms.

4.9.2.2 S_{wa} = the weighted average saturated surface-dry bulk specific gravity of the coarse and fine aggregate as determined in Step 6.

4.9.2.3 S_c = the specific gravity of Portland cement, or a Portland cement-fly ash blend. (The generally accepted value for the specific gravity of Portland cement is 3.15. A weighted average density for a Portland cement-fly ash blend would be determined as in Step 6.)

4.9.2.4 A = air content in percent as determined in Step 4.

4.9.2.5 W = the mixing water required with SSD aggregate in kilograms per cubic meter, as determined in Step 7.

4.9.2.6 C = the cementitious materials content in kilograms per cubic meter, as determined in Step 3.

4.10 Estimation of Combined Aggregate Amount.

4.10.1 The total amount of blended aggregate (coarse, blended and fine) required for the mix, in kilograms per cubic meter, is calculated by subtracting the amount of required water and cementitious material in kilograms per cubic meter of concrete as determined in Step 7 and Step 3 respectively, from the unit mass of fresh concrete determined in Step 8.

4.11 Adjustments for Aggregate Moisture.

4.11.1 The aggregate quantities actually weighed out for the concrete must allow for moisture in the aggregates. Bulk specific gravities on the basis of mass of saturated surface-dry aggregate and absorptions of both coarse and fine aggregates are determined according to standard test methods described in ASTM C 127 and C 128, respectively. Total moisture contents for both coarse and fine aggregates are determined according the ASTM C 566, “Standard Test Method for Total Moisture Content of Aggregate by Drying.”

4.12 Trial Batch Adjustments.

4.12.1 The calculated mix proportions should be checked by means of trial batches prepared and tested in accordance with ASTM C 192, “Standard Method of Making and Curing Concrete Test Specimens in the Laboratory.” The concrete should be checked for unit weight and yield (ASTM C 138, “Standard Test Method for Unit Weight, Yield, and Air Content [Gravimetric] of Concrete), for air content (ASTM C 231, “Air Content of Freshly Mixed Concrete by the Pressure Method), and for determining the minimum required flexural strength, ASTM C 78, “Flexural Strength of Concrete Using Simple Beam with Third-Point Loading.”

4.12.2 The concrete shall be proportioned for the minimum flexural strength required by the specification at 90 days of age determined using the procedures of ASTM C 78. Concrete beam specimens should be tested at ages of 7, 14, 28, and 90 days.

4.12.3 Adjustments to the mix to provide the required workability and air content should be made by adjustments in water content (though not to exceed a water cement ratio of 0.45) and by the use of chemical admixtures. Once the desired strength requirements are satisfied, two other concrete mixtures should be prepared having two different water cement ratios to evaluate their effect on flexural strength at 90 days.

4.13 Field Trials.

4.13.1 The contractor should place a test strip of pavement representing 2 hours of mixing and placing operations and using that concrete and equipment that will be used to perform the work. The contractor should demonstrate that positive control of edge slump and surface finish can be established and maintained. The contractor should also demonstrate that this control can be maintained when environmental conditions change.

Chapter 5

REFERENCES

5.1 Department of the Army, Corps of Engineers, Handbook for Concrete and Cement.

5.1.1 CRD-C 5 Concrete Within Batch Uniformity (used for determination of the minimum time of mixing)

5.1.2 CRD-C 100 Sampling Concrete Aggregate and Aggregate Sources and Selection of Material for Testing

5.1.3 CRD-C 119 Flat and Elongated Particles in Coarse Aggregate (Rev Jun 1963)

5.1.4 CRD-C 143 Meters for Automatic Indication of Moisture in Fine Aggregate

5.1.5 CRD-C 300 Membrane-Forming Compounds for Curing Concrete

5.1.6 CRD-C 400 Water for Use in Mixing or Curing Concrete

5.2 American Society for Testing and Materials (ASTM) Publications.

5.2.1 C 29 Unit Weight and Voids in Aggregate

5.2.2 C 31 Making and Curing Concrete Test Specimens in the Field

5.2.3 C 33 Concrete Aggregates

5.2.4 C 39 Compressive Strength of Concrete Cylinders

5.2.5 C 70 Surface Moisture in Fine Aggregate (R 1985)

5.2.6 C 78 Flexural Strength of Concrete Using Simple Beam with Third-Point Loading

5.2.7 C 117 Materials Finer Than 75- (No. 200) Sieve in Mineral Aggregates by Washing

5.2.8 C 123 Lightweight Pieces in Aggregate

5.2.9 C 125 Standard Definitions of Terms Relating to Concrete and Concrete Aggregates

5.2.10 C 127 Standard Test Method for Specific Gravity and Absorption of Coarse Aggregate

5.2.11 C 128 Standard Test Method for Specific Gravity and Absorption of Fine Aggregate

5.2.12 C 136 Sieve Analysis of Fine and Coarse Aggregates

5.2.13 C 138 Standard Test Method for Unit Weight, Yield, and Air Content (Gravimetric) of Concrete

5.2.14 C 142 Clay Lumps and Friable Particles in Aggregates (R 1990)

5.2.15 C 143 Standard Test Method for Slump of Portland Cement Concrete

5.2.16 C 150 Portland Cement

5.2.17 C 172 Sampling Freshly Mixed Concrete

5.2.18 C 183 Standard Methods of Sampling and Acceptance of Hydraulic Cement

5.2.19 C 192 Standard Method of Making and Curing Concrete Test Specimens in the Laboratory

5.2.20 C 231 Air Content of Freshly Mixed Concrete by the Pressure Method

5.2.21 C 260 Air-Entraining Admixtures for Concrete

5.2.22 C 295 Petrographic Examination Aggregates for Concrete

5.2.23 C 311 Sampling and Testing Fly Ash or Natural Pozzolans for Use as a Mineral Admixture

5.2.24 C 494 Chemical Admixtures for Concrete

5.2.25 C 566 Total Moisture Content of Aggregate by Drying

5.2.26 C 595 Standard Specification for Blended Hydraulic Cements

5.2.27 C 618 Fly Ash and Raw or Natural Pozzolan for Use as a Mineral Admixture in Portland Cement Concrete

5.2.28 C 851 Scratch Hardness of Coarse Aggregate Particles

5.2.29 C 881 Epoxy-Resin-Base Bonding Systems for Concrete

5.2.30 C 1157M Standard Performance Specification for Blended Hydraulic Cement

5.2.31 D 75 Standard Practice for Sampling Aggregates

5.3 American Concrete Institute.

5.3.1 SP 140 High Performance Concrete in Severe Environments

5.3.2 116R Cement and Concrete Terminology, SP-19(78)

5.3.3 201.2R Guide to Durable Concrete (Reaffirmed 1982)

5.3.4 211.1 Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete

5.3.5 212.1R Admixtures for Concrete

5.3.6 212.2R Guide for Use of Admixtures in Concrete

5.3.7 304 Recommended Practice for Measuring, Mixing, Transporting, and Placing Concrete (Reaffirmed 1978)

5.3.8 304R Guide for Measuring, Mixing, Transporting, and Placing Concrete

5.3.9 305R Hot Weather Concreting

5.3.10 306R Cold Weather Concreting

5.3.11 316R Recommendations for Construction of Concrete Pavements and Concrete Bases

Chapter 6

SAMPLE COMPUTATIONS

6.1 Example No. 1.

6.1.1 **General Description.**

6.1.2 This example illustrates how fine aggregate that does not meet the grading requirements of ASTM C-33, but when combined with coarse aggregate in the correct proportions, the total aggregate grading falls into the correct zone for slipform paving according to the Aggregate Proportioning Guide for combined aggregate gradings.

6.1.3 Concrete is required for an airfield taxiway at Tyndall AFB in Florida. The exposure is considered mild as designated by ACI 211. The limits for deleterious substances and physical property requirements of the coarse aggregate and fine aggregate can be found in Table 3, class designation 1N, and Table 1 respectively in ASTM C 33. The contractor plans to use slipform paving equipment to place the concrete, requiring the workability of the concrete mixture be appropriate for use with that type of equipment. Structural considerations require a flexural strength of 5 MPa (750 psi) at 90 days. Type I Portland cement will be used having a specific gravity of 3.15.

6.1.4 The crushed limestone coarse aggregate available for the job corresponds to size number 467 having a nominal maximum size of 37.5mm to No. 4 according to ASTM C 33, Table 2, "Grading Requirements for Coarse Aggregate." The sieve analysis for the No. 467 coarse aggregate and the coarse aggregate grading are shown in Table 6.1 and Figure 6.1, respectively.

TABLE 6.1 Coarse Aggregate Sieve Analysis and ASTM C33 Limits for No. 467 Grading

Sieve Size	ASTM C33 Grading Limit (min)	ASTM C33 Grading Limit (max)	% Passing No. 467
50mm	100	100	100
37.5mm	95	100	96.6
19mm	35	70	53.7
9.5mm	10	30	16.2
#4	0	5	2

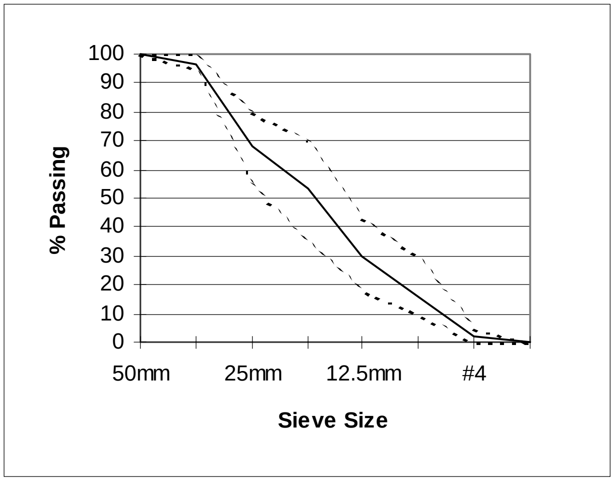


Figure 6.1 Grading of 37.5mm Nominal Coarse Aggregate and ASTM C33 Grading Limits

6.1.5 The coarse aggregate has a bulk specific gravity (saturated surface-dry) of 2.69 and an absorption of 0.33 percent. The dry-rodded mass of the coarse aggregate is 1650 kilograms per cubic meter (103 pcf).

6.1.6 The fine aggregate is a manufactured sand consisting of limerock screenings designated as FDOT Code #25 - Fine Screenings, and has a bulk specific gravity (saturated surface-dry) of 2.68, an absorption of 1.71 percent, and fineness modulus of 3.15. The fine aggregate sieve analysis, fineness modulus calculation, and grading are shown in Table 6.2 and Figure 6.2, respectively. The minimum fineness modulus required by the USAF is 2.3, and the maximum limitation of ASTM C33 for fineness modulus of 3.1 is NOT applicable for fine aggregate being used in this example. The fineness modulus (FM) is determined by summing the percent cumulative retained values from the sieves shown in Table 6.2, and the result (315), divided by 100, yields a FM value of 3.15.

TABLE 6.2 Fine Aggregate Sieve Analysis and ASTM C33 Fine Aggregate Grading

	ASTM C33	ASTM C33	% Passing	% Cumulative Retained
Sieve Size	Grading Limit (min)	Grading Limit (max)	FDOT#25	FDOT#25
9.5mm	100	100	100	0
4	95	100	89	11
8	80	100	73	27
16	50	85	47	53
30	25	60	38	62
50	5	30	25	75
100	0	10	13	87
				315

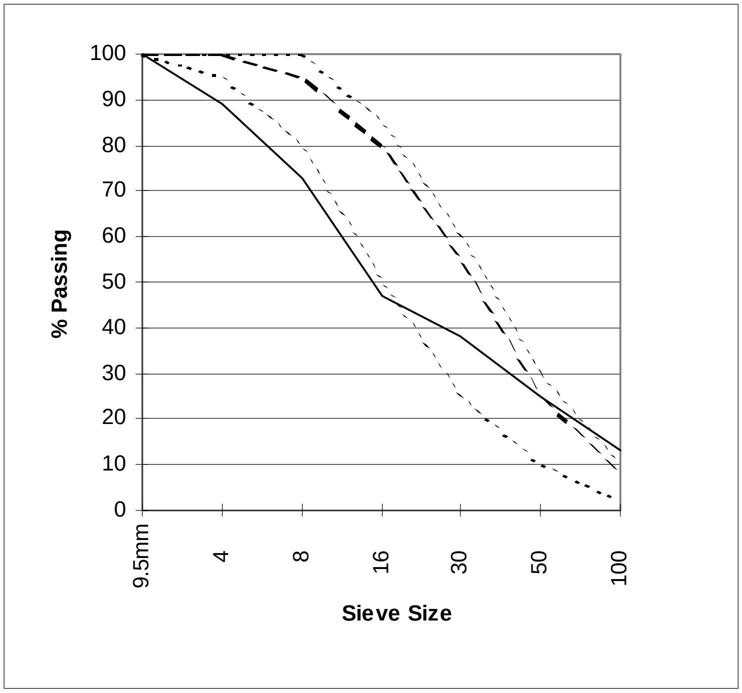


Figure 6.2 Grading of Fine Aggregate and Grading Limits of Fig. 3.11

6.2 The quantities of ingredients per cubic meter of concrete are calculated as follows:

6.2.1 Step 1 - Mix workability was determined by the contractor as appropriate for placement by a slipform paver.

6.2.2 Step 2 - The locally available coarse aggregate having a nominal maximum size of 37.5mm, and graded from 37.5mm to No. 4, has been determined to be suitable for this paving project.

6.2.3 Step 3 - The amount of cementitious material in the form of Type I Portland cement was chosen to be 335 kilograms per cubic meter (564 pcy) of concrete, meeting the minimum cementitious materials factor specified in this handbook.

6.2.4 Step 4 - From Table 4.1, the amount of air, based on the nominal maximum aggregate size of 37.5mm, and being in a mild exposure region, should be 2 1/2 percent within -1 to +2 percentage points.

6.2.5 Step 5 - The ratio of coarse to fine aggregate for the combined aggregate is determined from both the Aggregate Proportioning Guide and the Percent

Combined Aggregate Retained Graph. The amount of coarse aggregate and fine aggregate is treated as a single component of the mix, and the amount of the combined aggregate will be determined in Step 9 of this sequence.

6.2.5.1 The individual coarse and fine aggregate sieve analyses and the combined sieve analysis based on 58 percent coarse and 42 percent fine aggregate are shown in Table 6.3. This ratio is determined by trial-and-error until the combination of available aggregates meet the requirements specified by the Aggregate Proportioning Guide and the Percent Combined Aggregate Retained Graph as defined in Chapter 3 of the handbook. The workability factor, defined as the amount of combined aggregate material passing the No. 8 sieve multiplied by 100, is shown to be 30.66. The coarseness factor, defined as the percent of combined aggregate retained above the 9.5mm sieve divided by that which is retained above the No. 8 sieve, this ratio multiplied by 100, is calculated to be 70.1.

TABLE 6.3 Sieve Analysis of Combined Aggregate

Sieve Size	% Passing Coarse Aggregate	% Passing Fine Aggregate	Combined % Passing	Combined % Cumulative Retained	Combined % Retained
50mm	100	100	100.00	0.00	0
37.5mm	96.6	100	98.03	1.97	1.97
25mm	68.4	100	81.67	18.33	16.36
19mm	53.7	100	73.15	26.85	8.53
12.5mm	30.2	100	59.52	40.48	13.63
9.5mm	16.2	100	51.40	48.60	8.12
4	2	89	38.54	61.46	12.86
8	0	73	30.66	69.34	7.88
16		47	19.74	80.26	10.92
30		38	15.96	84.04	3.78
50		25	10.50	89.50	5.46
100		13	5.46	94.54	5.04

WF=30.66 CF=70.10

6.2.5.2 The plot of the combined aggregate on the Aggregate Proportioning Guide, and the Percent Aggregate Retained Graph are shown in Figures 6.3 and 6.4, respectively. The 58 percent coarse and 42 percent fine combined aggregate data point, in Figure 6.3, is located just above the centerline within the workability box, which is just where it should be for placing concrete using slipform paving equipment. Since the combined aggregate data point is close to being outside of the workability box and does not include the daily variance, frequent checks on the combined aggregate gradation will be required. The Percent Combined Aggregate Retained plot of the combined aggregate, in Figure 6.4, shows no significant valley or peak between the 9.5mm sieve size and the finest reporting sieve size.

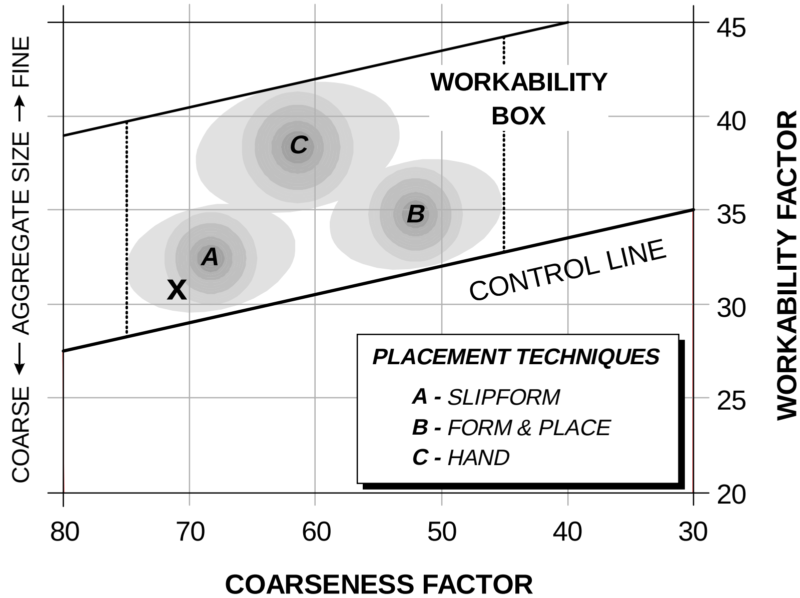


Figure 6.3 Aggregate Proportioning Guide for Combined Aggregate

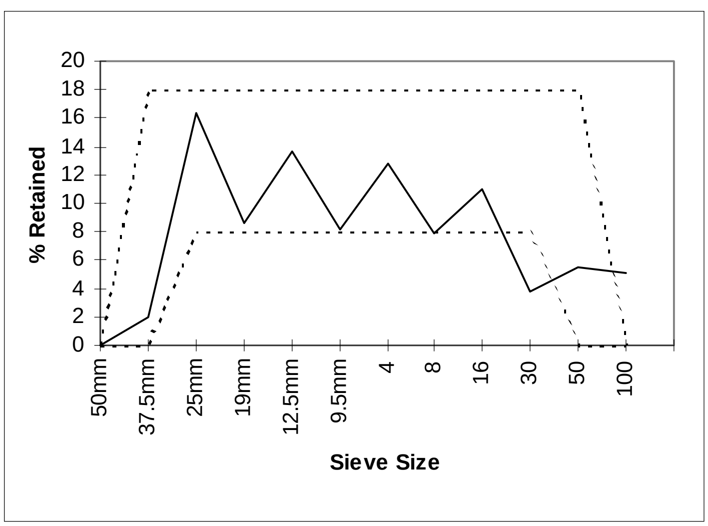


Figure 6.4 Percent Combined Aggregate Retained Graph

6.2.6 Step 6 - The weighted average specific gravity (ssd) for the combined aggregate is calculated from the ratio of coarse aggregate to fine aggregate that satisfies the aggregate grading control requirements as specified by the Aggregate Proportioning Guide and the Percent Combined Aggregate

Retained criteria, and the bulk specific gravities (ssd) of the individual aggregate fractions. The ratio that satisfies the criteria of Step 5 was 58 percent by mass coarse aggregate and 42 percent by mass fine aggregate. Therefore, the weighted average specific gravity (ssd) of the aggregate blend is calculated by the following:

6.2.6.1 $S_{wa(ssd)} = (\%CA*S_{ca(ssd)} + \%BA*S_{ba(ssd)} + \%FA*S_{fa(ssd)})/100$

where:

6.2.6.2 $\%CA = 58$

6.2.6.3 $S_{ca(ssd)} = 2.69$

6.2.6.4 $\%BA = 0$

6.2.6.5 $S_{ba(ssd)} = 0$

6.2.6.6 $\%FA = 42$

6.2.6.7 $S_{fa(ssd)} = 2.68$

6.2.6.8 $S_{wa(ssd)} = ((58)*(2.69) + (42)*(2.68))/100 = 2.69$

6.2.7 <u>Step 7</u> - The water cementitious ratio required to produce the required workability for slipform paver placement can be determined by laboratory testing and field trial batches, and shall not exceed the 0.45 maximum. The initial estimate of water cementitious ratio was taken to be between 0.40-0.42, and trial batches made. A starting point for the water cementitious ratio used in this example was 0.40. A water content of 134 kilograms per cubic meter (225.6 pcy**)** of concrete is required based on a cement content of 335 kilograms per cubic meter (564 pcy**)** of concrete and a water cementitious ratio of 0.4.

6.2.7.1 $W = (335\ kg/m^3)*(0.4) = 134\ kg/m^3$

6.2.8 <u>Step 8</u> - The unit mass of fresh concrete per cubic meter of concrete is calculated next using the formula described in ACI 211.1.

6.2.8.1 $U = 10*S_{wa}*(100-A) + C*(1-S_{wa}/S_c) - W*(S_{wa}-1)$

where:

6.2.8.2 $S_{wa} =$ 2.69

6.2.8.3 $S_c =$ 3.15

6.2.8.4 $A =$ 2.5 percent

6.2.8.5 $W =$ 134 kg

6.2.8.6 $C =$ 335 kg

6.2.8.7 $U =$ 2445 kg/m^3

6.2.9 Step 9 - The total amount of combined aggregate required for the mix in Kg per cubic meter (pcy) of concrete is calculated by subtracting the amount of required water and cementitious material from the unit mass of fresh concrete determined in Step 8.

6.2.9.1 For 1 cubic meter of concrete:

6.2.9.2 2445 kg/m^3 (4115 pcy) total mass - 335 kg/m^3 (564 pcy) of cement - 134 kg/m^3 (225.6 pcy) of water = 1976 kg/m^3 (3325 pcy) of combined aggregate (ssd)

6.2.9.3 Of the 1976 kg/m^3 (3325 pcy) of combined aggregate calculated in Step 9, 58 percent or 1146 kg/m^3 (1929 pcy) of coarse aggregate(ssd), and 42 percent or 830 kg/m^3 (1396 pcy) of fine aggregate(ssd).

6.2.9.4 The estimated batch weights for a cubic meter of concrete, in kilograms are:

Water (mix)	134 kg
Cement	335 kg
Coarse aggregate (ssd)	1146 kg
Fine aggregate (ssd)	830 kg
Total mass	2445 kg

6.2.9.5 From an absolute volume basis per cubic meter are:

Water (mix)	134/1000 =	0.134
Cement	335/(3.15*1000) =	0.1063
Coarse aggregate (ssd)	1146/(2.69*1000) =	0.426
Fine aggregate (ssd)	830/(2.68*1000) =	0.3097
Air	0.025*1.0 =	0.025
Total volume		1.00 m^3

6.2.10 Step 10 - Tests indicate total moisture contents of 3 percent over saturated surface-dry in the coarse aggregate and 5 percent over ssd in the fine aggregate. Adjusted coarse and fine aggregate mass, in kilograms per cubic meter of concrete then becomes:

6.2.10.1 Coarse aggregate (wet) = 1146*(1.03) = 1180 kg/m^3(1987 pcy)
Fine Aggregate (wet) = 830*(1.05) = 872 kg/m^3 (1466 pcy)

6.2.10.2 The required amount of mix water, in kilograms per cubic meter is then reduced to:

6.2.10.3 134 - 1146*(0.03) - 830(0.05) = 58.1 kg/m^3 (97.93 pcy)

6.2.10.4 The estimated adjusted batch weights, in kilograms per cubic meter of concrete are:

Water (to be added)	58.1 kg
Cement	335 kg
Coarse aggregate (wet)	1180 kg
Fine aggregate (wet)	872 kg
Total mass	2445.1 kg

6.2.11 Step 11 - Laboratory trial batches are produced and tested in accordance with ASTM C 192, "Standard Method of Making and Curing Concrete Test Specimens in the Laboratory." The concrete is checked for unit weight and yield, ASTM C138, "Standard Test Method for Unit Weight, Yield, and Air Content (Gravimetric) of Concrete," for air content, ASTM C 231, "Air Content of Freshly Mixed Concrete by the Pressure Method," and for determining the minimum required flexural strength, ASTM C 78, "Flexural Strength of Concrete Using Simple Beam with Third-Point Loading."

6.2.11.1 Adjustments to the mix to provide the required workability and air content should be made by adjustments in water content (though not to exceed a water cementitious ratio of 0.45) and by the use of chemical admixtures. Once the desired strength requirements are satisfied, two other concrete mixtures were prepared having two different water cement ratios to evaluate their effect on flexural strength at 90 days.

6.2.12 Step 12 - The contractor placed a test strip of pavement representing 2 hours of mixing and placing operations and using that concrete and equipment to perform the work. The contractor demonstrated that positive control of edge slump and surface finish could be established and maintained. He also demonstrated that this control could be maintained according to environmental conditions.

6.3 Example No. 2.

6.3.1 **General Description.**

6.3.2 Concrete is required for an airfield runway at McConnell AFB, Kansas. The exposure is considered severe as designated by ACI 211. The limits for deleterious substances and physical property requirements of the coarse aggregate and fine aggregate can be found in Table 3, class designation 4S, and Table 1, respectively, in ASTM C 33. The contractor plans to use slipform paving equipment to place the concrete, requiring the workability of the concrete mixture be appropriate for use with that type of equipment. Structural considerations require a flexural strength of 5 MPa (750 psi) at 90 days. Type II Portland cement will be used having a specific gravity of 3.15.

6.3.3 The crushed limestone coarse aggregate available for the job corresponds to size No. 67 having a nominal maximum size of 19mm to No. 4 according to ASTM C 33-93, Table 2, "Grading Requirements for Coarse Aggregate." The sieve analysis for the No. 67 coarse aggregate and the coarse aggregate grading are shown in Table 6.4 and Figure 6.5, respectively.

TABLE 6.4 Coarse Aggregate Sieve Analysis and ASTM C 33 Limits for No. 67 Grading

	ASTM C33	ASTM C33	% Passing
Sieve Size	Grading Limit (min)	Grading Limit (max)	No. 67
25mm	100	100	100
19mm	90	100	97.24
9.5mm	20	55	33.59
#4	0	10	2.88
#8	0	5	0.57
#16	0	0	0

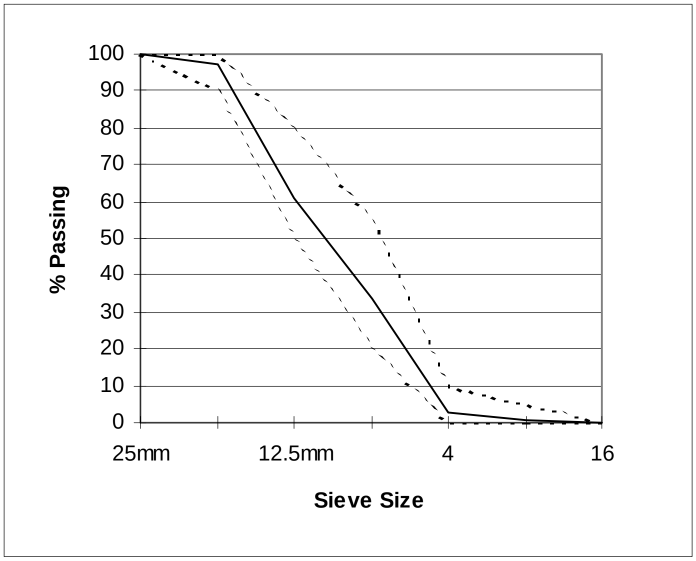


Figure 6.5 Grading of 19mm Nominal Coarse Aggregate and ASTM C33 Grading Limits

6.3.4 The coarse aggregate has a bulk specific gravity (saturated surface dry) of 2.69 and an absorption of 0.33 percent. The dry-rodded unit mass of the coarse aggregate is 1570 kilograms per cubic meter (98 pcf).

6.3.5 The fine aggregate is a manufactured stone sand, and has a bulk specific gravity (saturated surface-dry) of 2.76, an absorption of 3.3 percent, and fineness modulus of 3.12. The fine aggregate sieve analysis, fineness modulus calculation, and grading are shown in Table 6.5 and Figure 6.6, respectively. The minimum fineness modulus required by the USAF is 2.3, and the maximum limitation of ASTM C 33 for fineness modulus of 3.1 is NOT applicable for fine aggregate being used in this example. The fineness modulus (FM) is determined by summing the percent cumulative retained values from the sieves shown in Table 6.5, and the result (312), divided by 100, yields a FM value of 3.12.

TABLE 6.5 Fine Aggregate Sieve Analysis and ASTM C33 Fine Aggregate Grading

	ASTM C33	ASTM C33	% Passing	% Cumulative Retained
Sieve Size	Grading Limit (min)	Grading Limit (max)	Stone sand	Stone Sand
9.5mm	100	100	100	0
4	95	100	99	1
8	80	100	86	14
16	50	85	50	50
30	25	60	30	70
50	5	30	16	84
100	0	10	7	93
				312

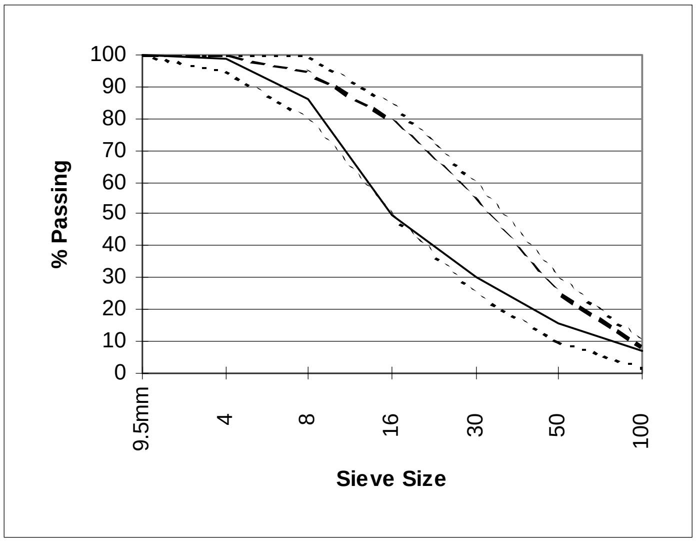


Figure 6.6 Grading of Fine Aggregate and Grading Limits of Fig. 3.11

6.4 The quantities of ingredients per cubic meter of concrete are calculated as follows:

6.4.1 Step 1 - Mix workability was determined by the contractor as appropriate for placement by a slipform paver.

6.4.2 Step 2 - The locally available coarse aggregate having a nominal maximum size of 19mm and graded from 19mm to No. 4, has been determined to be suitable for this paving project.

6.4.3 Step 3 - The amount of cementitious material in the form of Type II Portland cement was chosen to be 363 kilograms per cubic meter (611 pcy) of concrete, meeting the minimum cementitious materials factor specified in this handbook.

6.4.4 Step 4 - From Table 4.1, the amount of air, based on the nominal maximum aggregate size of 19mm, and being in a severe exposure region, should be 6 percent within -1 to +2 percentage points.

6.4.5 Step 5 - The ratio of coarse to fine aggregate for the combined aggregate is determined from both the Aggregate Proportioning Guide and the Percent Combined Aggregate Retained Graph. The amount of coarse aggregate and fine aggregate is treated as a single component of the mix, and the amount of the combined aggregate will be determined in Step 9 of this sequence.

6.4.5.1 The individual coarse and fine aggregate sieve analyses and the combined sieve analysis based on 62 percent coarse and 38 percent fine aggregate are shown in Table 6.6. This ratio is determined by trial-and-error until the combination of available aggregates meet the requirements specified by the Aggregate Proportioning Guide and the Percent Combined Aggregate Retained Graph as defined in Chapter 3 of the handbook. The workability factor, defined as the amount of combined aggregate material passing the No. 8 sieve, is shown to be 33.03. An additional 1.25 percent is added to the 33.03 determined from the percent passing the No. 8 sieve, since the cement factor of 363 kg/m^3 (611 pcy) is 28 kg/m^3 (47 pcy) more than the base cement factor. Therefore, the adjusted workability factor is 34.28. A 2.5 percent adjustment in the workability factor is required for each 56 kg/m^3 (94 pcy) of cement above the base cement factor of 335 kg/m^3 (564 pcy). The coarseness factor, defined as the percent of combined aggregate retained above the 9.5mm sieve divided by that which is retained above the No. 8 sieve multiplied by 100, is calculated to be 61.48.

TABLE 6.6 Sieve Analysis of Combined Aggregate

	% Passing	% Passing	Combined	Combined	Combined
Sieve Size	Coarse Aggregate	Fine Aggregate	% Passing	% Cumulative Retained	% Retained
1	100	100	100.00	0.00	0.00
3/4	97.24	100	98.29	1.71	1.71
1/2	60.65	100	75.60	24.40	22.69
3/8	33.59	100	58.83	41.17	16.78
4	2.88	99	39.41	60.59	19.42
8	0.57	86	33.03	66.97	6.37
16	0	50	19.00	81.00	14.03
30		30	11.40	88.60	7.60
50		16	6.08	93.92	5.32
100		7	2.66	97.34	3.42

WF=33.03   CF=61.48

6.4.5.2 The plot of the combined aggregate on the Aggregate Proportioning Guide, and the Percent Aggregate Retained Graph are shown in Figures 6.7 and 6.8, respectively. The 60 percent coarse and 40 percent fine aggregate combined aggregate data point, in Figure 6.7, is located just above the centerline within the workability box, which is just where it should be for placing concrete using a slipform paving equipment. However, this does not include the expected daily variance. The Percent Combined Aggregate Retained plot of the combined aggregate, in Figure 6.8, shows no significant valley or peak between the 9.5mm sieve size and the finest reporting sieve size.

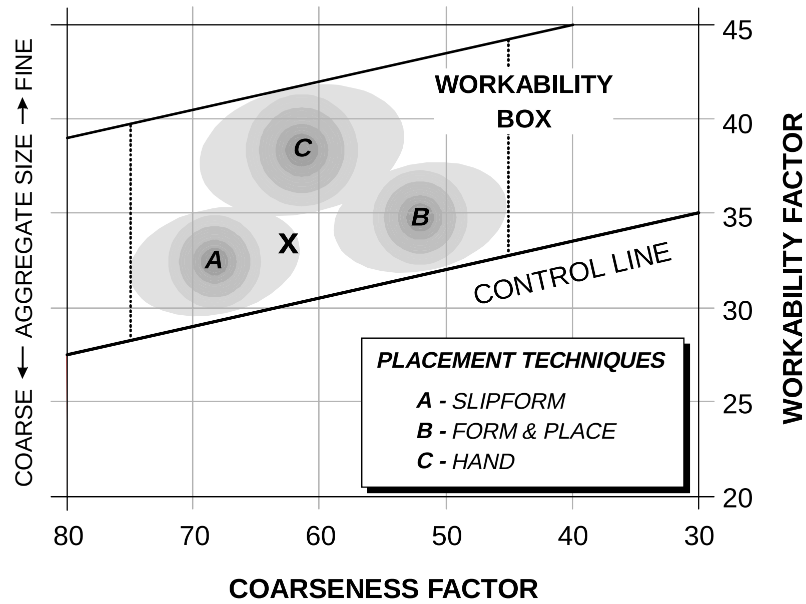


Figure 6.7 Aggregate Proportioning Guide for Combined Aggregate

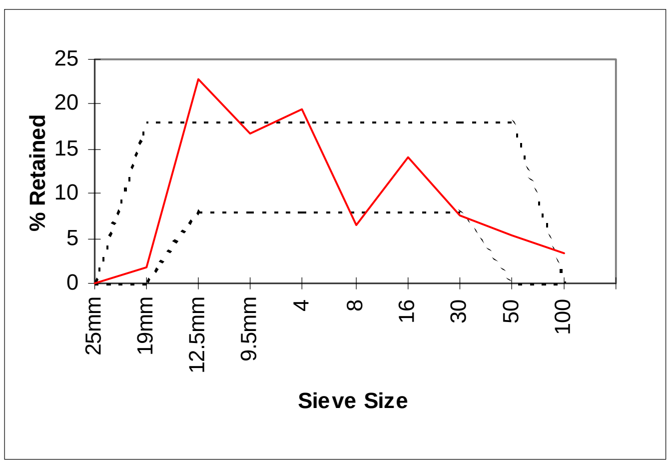


Figure 6.8 Percent Combined Aggregate Retained Graph

6.4.6 Step 6 - The weighted average specific gravity (ssd) for the combined aggregate is calculated from the ratio of coarse aggregate to fine aggregate that satisfies the aggregate grading control requirements as specified by the Aggregate Proportioning Guide and Percent Combined Aggregate Retained criteria, and the bulk specific gravity's (ssd) of the individual aggregate fractions. The ratio that satisfies the criteria of Step 5 was 62 percent by weight coarse aggregate and 38 percent by weight fine aggregate. Therefore, the weighted average specific gravity (ssd) of the aggregate blend is calculated by the following:

6.4.6.1 $S_{wa(ssd)} = (\%CA*S_{ca(ssd)} + \%BA*S_{ba(ssd)} + \%FA*S_{fa(ssd)})/100$

where:

6.4.6.2 $\%CA = 62$

6.4.6.3 $S_{ca(ssd)} = 2.69$

6.4.6.4 $\%BA = 0$

6.4.6.5 $S_{ba(ssd)} = 0$

6.4.6.6 $\%FA = 38$

6.4.6.7 $S_{fa(ssd)} = 2.76$

6.4.6.8 $S_{wa(ssd)} = ((62)*(2.69) + (38)*(2.76))/100 = 2.72$

6.4.7 Step 7 - The water cementitious ratio required to produce the required workability for slipform paver placement can be determined by laboratory testing and field trial batches, and shall not exceed the 0.45 maximum. The initial estimate of water cementitious ratio was taken to be between 0.40-0.42, and trial batches made. A starting point for the water cementitious ratio used in this example was 0.42. A water content of 152 kilograms per cubic meter (257 pcy) of concrete is required based on a cement content 363 kilograms per cubic meter (611 pcy) of concrete and a water cementitious ratio of 0.42.

6.4.7.1 $W = (363\ kg/m^3)*(0.42) = 152\ kg/m^3$

6.4.8 Step 8 - The unit mass of fresh concrete per cubic meter of concrete is calculated next using the formula described in ACI 211.1.

6.4.8.1 $U = 10* S_{wa} *(100\text{-}A) + C*(1- S_{wa} /S_c) - W*(S_{wa} -1)$

where:

6.4.8.2 $S_{wa} = 2.72$

6.4.8.3 $S_c = 3.15$

6.4.8.4 A = 6 percent

6.4.8.5 W = 152 kg

6.4.8.6 C = 363 kg

6.4.8.7 $U = 2345\ kg/m^3$

6.4.9 Step 9 - The total amount of combined aggregate required for the mix in kilograms per cubic meter (pcy) of concrete is calculated by subtracting the amount of required water and cementitious material from the unit mass of fresh concrete determined in Step 8.

6.4.9.1 For 1 cubic meter of concrete:

6.4.9.2 2345 kg/m^3 (3954 pcy) total mass - 363 kg/m^3 (611 pcy) of cement - 152 kg/m^3 (256.6 pcy) of water = 1830 kg/m^3 (3078 pcy) of combined aggregate(ssd).

6.4.9.3 Of the 1830 kg/m^3 (3084 pcy) of combined aggregate calculated in Step 9, 62 percent or 1135 kg/m^3 (1912 pcy) of coarse aggregate(ssd), and 38 percent or 695 kg/m^3(1172 pcy) of fine aggregate (ssd).

6.4.9.4 The estimated batch weights for a cubic meter of concrete, in kilograms are:

Water (mix)	152 kg
Cement	363 kg
Coarse aggregate (ssd)	1135 kg
Fine aggregate (ssd)	695 kg
Total weight	2345 kg

6.4.9.5 From an absolute volume basis per cubic meter are:

Water (mix)	152/1000 =	0.152
Cement	363/(3.15*1000) =	0.115
Coarse aggregate (ssd)	1135/(2.69*1000) =	0.421
Fine aggregate (ssd)	695/(2.76*1000) =	0.252
Air	0.06*1.0 =	0.06
Total volume		1.00 m^3

6.4.10 Step 10 - Tests indicate total moisture contents of 1 percent over saturated surface-dry in the coarse aggregate and 2 percent over SSD in the fine aggregate. Adjusted coarse and fine aggregate mass, in kilograms per cubic meter of concrete then become:

6.4.10.1 Coarse aggregate (wet) = 1135*(1.01) = 1146 kg/m^3 (1932 pcy) Fine Aggregate (wet) = 695*(1.02) = 709 kg/m^3 (1195 pcy)

6.4.10.2 The required amount of mix water, in kilograms per cubic meter is then reduced to:

6.4.10.3 $152 - 1135*(0.01) - 695(0.02) = 127.25$ kg/m^3 (214.5 pcy).

6.4.10.4 The estimated adjusted batch weights, in kilograms per cubic meter of concrete are:

Water (to be added)	127.25 kg
Cement	363 kg
Coarse aggregate (wet)	1146 kg
Fine aggregate (wet)	709 kg
Total weight	2345.25 kg

6.4.11 Step 11 - Laboratory trial batches are produced and tested in accordance with ASTM C 192, "Standard Method of Making and Curing Concrete Test Specimens in the Laboratory." The concrete is checked for unit weight and yield, ASTM C138, "Standard Test Method for Unit Weight, Yield, and Air Content (Gravimetric) of Concrete," for air content, ASTM C 231, "Air Content of Freshly Mixed Concrete by the Pressure Method," and for determining the minimum required flexural strength, ASTM C 78, "Flexural Strength of Concrete Using Simple Beam with Third-Point Loading."

6.4.11.1 Adjustments to the mix to provide the required workability and air content should be made by adjustments in water content (though not to exceed a water cementitious ratio of 0.45) and by the use of chemical admixtures. Once the desired strength requirements are satisfied, two other concrete mixtures were prepared having two different water cement ratios to evaluate their effect on flexural strength at 90 days.

6.4.12 Step 12 - The contractor placed a test strip of pavement representing 2 hours of mixing and placing operations and using that concrete and equipment to perform the work. The contractor demonstrated that positive control of edge slump and surface finish could be established and maintained. He also demonstrated that this control could be maintained according to environmental conditions.

UNITED STATES AIR FORCE GUIDE SPECIFICATION
MILITARY AIRFIELD CONSTRUCTION

****
Notes to the Specifier:

This specification should be used for airfield pavement re-construction or new construction where the placed concrete exceeds 3000 cubic meters.

These specifications must be modified to include applicable options. Where options are to be made, or elective procedures are to be specified, the sections are identified by a line of preceding asterisks, indentation, and following asterisks (as is this note). Prior to publication of these documents as part of the project, all comments/instructions/options which are identified as such are to be deleted from the text.

THIS SPECIFICATION ENCOURAGES "SHARED RESPONSIBILITY FOR THE PRODUCT" BETWEEN THE CONTRACTOR AND THE AIR FORCE. IT IS NECESSARY THAT THE ENGINEER AND THE CONTRACTOR MAINTAIN A POSITIVE PRESENCE ON THE WORK DURING THE PROGRESS OF THE WORK. THE INTENT OF THE SPECIFICATION IS TO USE PROCESS CONTROL TO IDENTIFY FAULTY MATERIALS AND/OR PROCEDURES PRIOR TO THE PLACEMENT OF FRESH CONCRETE.

THIS DOCUMENT WAS DEVELOPED WITH THE PARTICIPATION OF PROFESSIONAL ORGANIZATIONS WHICH REPRESENT THE CONCRETE PAVEMENT CONSTRUCTION INDUSTRY. MODIFICATIONS OF THE DOCUMENT MAY VIOLATE THE SPIRIT OF THAT PARTICIPATION. THEREFORE, APPROVAL OF MODIFICATION IS REQUIRED, BY HQ AFCESA/CES, FOR OTHER THAN DESIGNATED OPTIONS.

> *This guide specification incorporates a Quality Assurance/Quality Control (QA/QC) construction management philosophy. The Government will use the results from the testing of materials and/or products, accomplished by the Contractor, for "Assurance" that the construction, as placed, is in reasonable conformance with this specification. These QA results are used by the Government for acceptance of the built product. The QA monitor may be people in the employ of the government or people under contract through professional services agreements.*

The Contractor is required to provide testing services (QC) to monitor construction compliance with this specification.

When preparing contract documents for the construction of rigid pavement systems refer to: AFM 88-6, Chapter 8, "Standard Practice for Concrete Pavements"; AFP 88-71, "Standard Details for the Construction and Repair of Airfield Pavement Systems"; AFM 88-6, Chapter 7, "Standard Practice for Sealing Joints and Cracks in Rigid and Flexible Pavements"; and, AFM 88-6, Chapter 10, "Repair of Rigid Pavements Using Epoxy-Resin Grouts, Mortars, and Concretes."

The point of contact for this document is HQ AFCESA/CESC, 139 Barnes Drive-Suite 1, Tyndall AFB, FL, 32403-5319. The document coordinator is Mr Jim Lafrenz on (904) 283 6332 or E-mail lafrenzj@afcesa.af.mil.
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RIGID CONCRETE PAVEMENT FOR AIRFIELDS

SECTION ____

PART 1 - GENERAL

1.1 <u>APPLICABLE PUBLICATIONS</u>: The publications listed below form a part of this specification. The publications are referred to in the text by basic designation only.

****
The designations for publications are those that were in effect when this guide specification was prepared. To minimize the possibility of error, the letter suffixes, amendments, and dates indicating specific issues are retained here and are to be omitted in the project documents.
****

1.1.1 **Department of the Army, Corps of Engineers, Handbook for Concrete and Cement:**

CRD-C 55-91	Concrete Within Batch Uniformity (used for determination of the minimum time of mixing)
CRD-C 119-91	Flat and Elongated Particles in Coarse Aggregate (Rev Jun 1963)

CRD-C 400-63	Water for Use in Mixing or Curing Concrete

1.1.2 **American Society for Testing and Materials (ASTM) Publications:**

A 120-84	Pipe, Steel, Black and Hot-Dipped Zinc- Coated (Galvanized) Welded and Seamless, for Ordinary Uses
A l84/A 184M-90	Fabricated Deformed Steel Bar Mats for Concrete Reinforcement
A l85-94	Steel Welded Wire Fabric, Plain
A 497-94a	Welded Deformed Steel Wire Fabric for Concrete Reinforcement
A 6l5/A 615M-95b	Bars, Deformed and Plain, Billet-Steel, for Concrete Reinforcement
A 6l6/A 616M-95b	Bars, Deformed and Plain, Rail Steel, for Concrete Reinforcement
A 617/A 617M-95b	Bars, Deformed and Plain, Axle-Steel, for Concrete Reinforcement
C 3l-91	Making and Curing Concrete Test Specimens in the Field
C 33-93	Concrete Aggregates
C39-94	Compressive Strength of Concrete Cylinders
C 70-94	Surface Moisture in Fine Aggregate (R 1985)
C 75-87	Standard Practice for Sampling Aggregates
C 78-94	Flexural Strength of Concrete Using Simple Beam with Third-Point Loading
C-88-90	Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate
C l23-94	Lightweight Pieces in Aggregate
C-127-88	Standard Test Methods for Specific Gravity and Absorption of Coarse Aggregate

C-128-93	Standard Test Methods for Specific Gravity and Absorption of Fine Aggregate
C-131-89	Resistance to Degradation of Small Size Coarse Aggregate by the Los Angeles Abrasion Machine
C l36-95a	Sieve Analysis of Fine and Coarse Aggregates
C l42-78 (1990)	Clay Lumps and Friable Particles in Aggregates (R 1990)
C l50-95	Portland Cement
C 172-90	Sampling Freshly Mixed Concrete
C 23l-91b	Air Content of Freshly Mixed Concrete by the Pressure Method
C 260-94	Air-Entraining Admixtures for Concrete
C 289-94	Potential Alkali-Silica Reactivity of Aggregates
C 295-90	Petrographic Examination Aggregates for Concrete
C 309-94	Liquid Membrane-Forming Compounds for Curing Concrete
C 311-94b	Sampling and Testing Flyash or Natural Pozzolans for use as a Mineral Admixture
C 494-92	Chemical Admixtures for Concrete
C 535-89	Resistance to Degradation of Large Size Coarse Course Aggregate in the Los Angeles Abrasion Machine
C 566-89	Total Moisture Content of Aggregate by Drying
C 595M - 95	Blended Hydraulic Cements
C 618-89a	Fly Ash and Raw or Natural Pozzolan for Use as a Mineral Admixture in Portland Cement Concrete
C 881-90	Epoxy-Resin-Base Bonding Systems for Concrete
C 1064 - 86	Temperature of Freshly Mixed Portland Cement Concrete

D 1751	Preformed Expansion Joint Filler for Concrete Paving and Structural Construction (Nonextruding and Resilient Bituminous Types)
D l752	Preformed Sponge Rubber and Cork Expansion Joint Fillers for Concrete Paving and Structural Construction

1.1.3 **U.S. Department of Commerce, National Bureau of Standards:**

National Bureau of Standards (NBS) Handbook 44 - Specification, Tolerances, and Other Technical Requirements for Weighing and Measuring Devices.

1.2 ACCEPTANCE TESTING/ QUALITY CONTROL (QC) PROCEDURES:

1.2.1 **Acceptance Testing:** The Government may supplement the results of the material testing which is accomplished by the Contractor to evaluate construction for acceptance. The Contractor shall provide copies of all QC testing results and daily reports to the Contracting Officer representative within 24-hours of the work represented. The government may elect to supplement the quality control testing with quality assurance testing accomplished by another party.

1.2.2 **Quality Control (QC) Testing by Contractor:** The Contractor shall perform the Quality Control (QC) functions required by this specification. The QC Laboratory (QC LAB) shall accomplish concrete mixture proportioning and the daily monitoring of the concrete mixing and placing. The minimum daily monitoring requirements are described in paragraph **CONTRACTOR QUALITY CONTROL,** in Part 3, of this specification. Within 15 days after the Notice to Proceed date, the Contractor shall submit a qualifications statement of the proposed QC LAB. The Government will review the qualifications of the laboratory and, if necessary, visit the QC LAB. Evaluation criteria will include respective State or National accreditation and/or certification programs.

1.2.2.1 The Contractor shall retain the services of an independent commercial testing laboratory to perform the QC LAB functions; and/or,

1.2.2.2 The Contractor can use a contractor owned quality control staff provided that all of the following conditions are met to the satisfaction of the Contracting Officer.

a. The Contractor's quality control function is and has been a part of the organization for a minimum of 2-years;

b. Each quality control technician is qualified through certification by a national organization, or has a degree in a related engineering field;

c. The quality control manager shall be a full time employee of the Contractor, shall have a minimum of 5 years' experience in construction materials testing and shall have authority to stop all work associated with the incorporation of non-conforming materials into the project; and

d. Certification from a State or National entity that the equipment used by the Contractor to perform quality control testing conforms to the applicable testing standards and that calibrations of the testing equipment are current.

1.2.3 **Concrete Mixture Proportioning Studies:** After the aggregate source is approved, as described in paragraph **MATERIAL ACCEPTANCE TESTING,** below, and at least 45-days before the time when placing of concrete is expected to begin, the QC LAB shall start mixture proportioning studies.

1.2.4 **Pavement Construction Test Section:** The Contractor shall demonstrate performance to the intent of this specification.

1.2.4.1 The intent of the test section is to allow the Contractor to demonstrate that the concrete can be placed within the specified conditions. The Contractor is expected to adjust the mix, adjust equipment, and modify procedures such that by the end of the test strip the best possible product is attained. That part of the test strip which does not meet the minimum requirements of these specifications shall be removed and replaced without additional cost to the Government.

1.2.4.2 The Contractor shall demonstrate mixing, transporting, placing, finishing, application of cure, protection, construction of transverse joints, and the performance of the quality control functions specified. Any adjustments of the mix, placing, or finishing procedures to meet field conditions will be coordinated with the Contracting Officer representative prior to implementation by the Contractor. The Contractor shall obtain written approval of the test section, from the Contracting Officer, before proceeding with the work. The test section approval/rejection will be issued by the Government at the end of the day on which the test section is placed.

1.2.5 **Daily "Pour Agreement":** The Contractor, or designated representative, the Government representative, and the QC LAB representative shall sign an agreement at the close of each day of concrete placement. The agreement shall state that the procedures used for the day's placement meet or exceed the performance demonstrated at the test section and that the next placement may proceed. Any one of the signatory persons may elect to not sign. All signatory members have equal authority. When a signatory member does not sign, the reasons shall be stated and the deficiency corrected or agreement shall be made on the corrective action. Those people designated to execute the agreement shall be participants at the test section construction.

1.3. <u>MATERIAL ACCEPTANCE TESTING</u>:

1.3.1 Preconstruction Sampling and Testing:

1.3.1.1 **Aggregates:** Aggregates shall be produced from sources of the Contractor's choice. The aggregates shall be tested to determine specific gravity, absorption, Los Angeles abrasion, sulfate soundness, soundness, alkali or carbonate reaction, and organic impurities. A petrographic analysis shall be performed on all aggregates unless there is a record of performance, of at least five years, for the aggregate source.

1.3.1.2 **Sampling and Testing:** The Contractor shall accomplish aggregate sampling and testing of the aggregates for quality determination. The Government will observe the aggregate sampling. The Contractor shall provide split samples to the Government. All quality testing results shall be provided to the Contracting Officer at least 10 days before starting a mixture proportioning study.

1.3.1.3 **Portland Cement:** The Contractor shall submit the identity of the cement manufacturer, the engineering and chemical qualities of the cement, and a manufacturer's statement which states that the cement complies with the intent and requirements of this specification. The Contractor, or the supplier, is prohibited from changing cement sources during the progress of the work without submitting the same information which qualified the original source. The submittal shall be made at least 10 days before starting a mixture proportioning study. When the Contractor changes sources of cement, strength testing shall be accomplished as if the work were just beginning.

1.3.1.4 **Admixtures:** The Contractor may use admixtures. Within 15-days after date of notice to proceed, the Contractor shall provide a listing of all chemical and mineral admixtures proposed for use in the concrete mixture. The Contractor assumes all responsibility for the use of admixtures and the results of that election. All mixture proportioning studies will be accomplished with the proposed admixtures included.

1.3.1.4.1 **Chemical Admixtures:** The chemical admixtures used in the concrete mixture shall be chemically compatible and shall not result in an adverse chemical reaction when combined with other ingredients. The Contractor shall produce a history of performance when admixtures are being supplied by multiple vendors. High-range water-reducing admixtures are not allowed.

1.3.1.4.2 **Mineral Admixtures:** The Contractor may use flyash as a part of the concrete mixture. The Contractor shall submit, within 15-days after date of notice to proceed, data which identifies the source and the characteristics of the flyash proposed for use in the concrete mixture.

1.3.1.5 **Curing Compound:** At least 30 days before the material will be used on the work, the Contractor shall submit a manufacturer statement which certifies that the material conforms to the intent and requirements of these specifications. The Contractor shall not incorporate the curing compound into the work unless the Contracting Officer has provided specific written acceptance of the product proposed. The Contractor shall provide the Government a one gallon sample from the lot(s) of material used on the work at the beginning of the work.

1.3.1.6 **Epoxy-Resin Material:** At least 30 days before the material is used, the Contractor shall submit a warrant by the manufacturer that the material conforms to the requirements of these specifications. When epoxy resin arrives at the job site, the Government shall sample the material and may either test the sample or retain in storage.

1.4. **GRADE AND SURFACE-SMOOTHNESS REQUIREMENTS:** The finished surface of pavements shall conform to the elevations provided in the contract drawings. The smoothness requirements of Table 4.2 are applicable.

1.4.1 **Grade Control:** Line and grade shown on contract drawings shall be established and maintained by the Contractor. Elevations of bench marks at the site of work will be determined, established, and maintained by the Government.

1.4.2 **Plan Grade:** Finished surfaces shall conform to the grade and cross sections indicated on drawings. Deviations from the plan elevation will be permitted only where the proper functioning of drainage, appurtenant structures, or matching to existing pavement elevation is required. The grade controls of Table 1.4.2 shall not be exceeded.

****
The Table 1.4.2 is to be edited to delete the pavement category which does not apply to the work being specified. The Table 1.4.2 applies to operational surfaces only. Criteria for shoulders, overruns, etc., should be specified in the surfacing specification for the respective pavement category. Reference AFR 86-14, Airfield and Heliport Planning Criteria, for criteria for other airfield pavement categories.

****

TABLE 1.4.2 GRADE CONTROLS FOR AIRFIELD PAVEMENT OPERATING SURFACES

Pavement Category	Longitudinal	Transverse
Runway	Max Grade 1.0%. Maximum 0.167% change per 30 linear meters of runway.	Max Grade 1.5% Min Grade 1.0%
Taxiway	Max Grade 1.5%. Maximum 1.0% change per 30 linear meters of taxiway.	Max Grade 1.5% Min Grade 1.0%
Apron	Max Grade 1.5% Min Grade 0.5%	Max Grade 1.5% Min Grade 0.5%
Other	Same as Apron	Same as Apron

Notes for Table 1.4.2:
(1) On runways, the maximum rate of longitudinal grade change is produced by vertical curves having 185 meter lengths for each percent of algebraic difference between two grades. A grade change is not allowed within the first 915 meters from the runway end.
(2) On runways, the transverse grade is to remain constant except at intersections where pavement surfaces must be warped.
(3) On taxiways, the minimum distance between two points of intersection for a change in grade is 150 meters. Changes in grade are done using vertical curves.

1.4.3 **Surface Smoothness:**

1.4.3.1 **Surface Smoothness:** Finished surfaces shall not deviate from the testing edge of a 3.5 meter straightedge more than tolerances shown for the respective pavement category in Table 1.4.3.

****
The Table 1.4.3 shall be edited to delete the pavement category(s) which do not apply to the proposed work.
****

TABLE 1.4.3. SURFACE-SMOOTHNESS TOLERANCES

Pavement Category	**Direction of Testing**	**Allowable Tolerance**
Runway and Taxiway	Longitudinal	3 mm
	Transverse	6 mm
Calibration Stands and Compass Swing Bases	Longitudinal	5 mm
	Transverse	5 mm
All Other Airfield Areas	Longitudinal	6 mm
	Transverse	6 mm

1.4.3.2 **Edge Slump:** Edge slump is the downward movement of the concrete along the pavement edge measured not more than 450 millimeters from the free edge. When a slip-form paver is used, 85 percent of the pavement, within a distance of one full slab length, shall have an edge slump less than 6 millimeters, and 100 percent of the pavement, within a distance of one full slab length, shall have an edge slump less than 9.5 millimeters. Edge slump will be determined by using the procedures described in paragraph **EDGE SLUMP DETERMINATION,** below. The use of paving equipment and/or procedures that fail to provide pavement edges within the above limitations shall not be allowed.

1.4.4 **Surface Evaluation Techniques:** The finished surface shall be evaluated for conformance with the plan grade and surface smoothness and edge slump by the Contractor.

1.4.4.1 **Equipment:** The Contractor shall furnish and keep at the job site one 3.5 meter straightedge for each operating paver. The straightedge shall be used for testing the surface smoothness and/or edge slump of placed concrete. Wood shall not be used. The straightedge shall have a flat bottom and shall be adequately rigid to assure accuracy.

1.4.4.2 **Surface-Smoothness Determinations:** When the concrete is hard enough to walk upon without damage to the surface, but not later than 24 hours after placement, the Contractor shall test the pavement surface for smoothness. The testing will be observed by the Government. Testing shall be accomplished using a 3.5 meter straightedge which shall be placed to reveal surface irregularities. The entire area of the pavement shall be tested in both the longitudinal and transverse direction. The straightedge shall be held in contact with the surface and moved ahead one-half the length of the straightedge for each successive measurement and continuing across transverse joints.

1.4.4.2.1 **Deviations:** Deviations from the smoothness criteria caused by the edge slump shall not be considered. Deviations caused by high areas along construction joints shall be considered.

1.4.4.2.2 **High Areas:** The height of a high area on a pavement surface shall be determined by placing the center of the straightedge at the center of the high area and rocking the straightedge until one end comes in contact with the pavement. With one end of the straightedge grounded, measure the distance between the pavement surface and the bottom of the straightedge at the opposite end. One-half the measurement will be the high area height.

1.4.4.3 **Edge Slump Determination:** When the concrete will support walking without damage to the surface, the pavement shall be tested by the Contractor with a 3.5 meter straightedge. The edge slump shall be determined at each free edge of each paving lane. The straightedge will be placed transverse to the direction of paving with the end of the straightedge at the free edge of the paving lane. Measurements will be made at increments of not more than one slab length.

1.4.5 **Surface Deficiencies and Corrections:**

1.4.5.1 **High Areas:** High areas shall be reduced by grinding the hardened concrete. Grinding shall only be accomplished when the concrete can support the weight of the equipment without damage to the surface.

1.4.5.2 **Excessive Edge Slump:** Adding concrete to or otherwise manipulating the fresh concrete shall not be used as a method to correct edge slump. Edge slump shall be corrected by adjustment of the concrete mixture or the paving machine. Where edge slump exceeds the allowable, the placed concrete exceeding the limits of edge slump shall be removed and replaced. Removal shall be done according to paragraph **REMOVAL AND REPLACEMENT OF DEFECTIVE CONCRETE**. Removal shall be across the full width of the pavement lane or to the nearest planned longitudinal joint when multiple lanes are placed. Removal shall be to the nearest planned transverse joints which isolates the edge slump deficiencies.

1.5. <u>EQUIPMENT AND CONSTRUCTION METHODS ACCEPTANCE</u>:

1.5.1 **Plant and Equipment:** The Contracting Officer representative retains right of access to Contractor's equipment during the progress of the work. The purpose is to evaluate operation of the plant, verify proportions, temperature, mixing time, and character of the materials. The Contractor shall submit descriptions of the equipment proposed for use on the project.

1.5.1.1 **Batch Plant and Mixers:** The Contractor shall submit detailed specifications of the concrete plant.

1.5.1.2 **Transport Equipment:** The Contractor shall provide the quantity and description of the equipment proposed for transporting concrete from the mixing plant to the placing equipment.

1.5.1.3 **Placing Equipment:** The Contractor shall describe the equipment proposed to place concrete.

1.5.1.4 **Finishing Equipment:** The Contractor shall describe the equipment proposed to finish the surface and the method of surface texturing.

1.5.2 **Construction Methods:** The Contracting Officer representative will review and approve (or reject) proposed special construction methods which may be necessary because of weather conditions encountered during the work.

1.5.2.1 **Cold Weather Requirements:** The Contractor shall prepare a cold weather concreting plan which describes the materials and methods to be used by the Contractor when protection is required.

1.5.2.2 **Hot Weather Requirements:** The Contractor shall prepare a plan which describes the methods and materials which shall be used to protect concrete under hot weather conditions. Hot weather conditions shall be assumed to prevail when the surface evaporation rate exceeds 0.2 pounds per square foot per hour as determined by using the chart included in ACI 305R-91, Hot Weather Concreting, Fig 2.1.5. All concrete placement shall cease when the temperature of the fresh concrete exceeds 90 degrees F.

1.5.3 **Pavement Test Section:**

1.5.3.1 **Construction Methods:** The Contractor shall place a pavement test section, within the limits of the work, at a location agreed to by the Contracting Officer and the Contractor. The Contractor shall place and finish concrete using the people, procedures, and equipment which will be used on the work. A minimum of 2 hours of mixing and placing concrete, at anticipated production capacity, shall be incorporated into the test section.

1.5.3.2 **Test Section Acceptance:** Those individuals designated to execute the daily pour agreements will observe the construction of the test section. When the section is rejected, or portions thereof, the cause shall be documented and reasons for rejection provided. The concrete placed within a test section that is not accepted shall be removed and replaced, by the Contractor, without cost to the government. The work will not proceed until the Contractor can demonstrate the placement and finish of an acceptable test section.

1.6 **<u>MATERIAL DELIVERY, STORAGE, AND HANDLING</u>:**

1.6.1 **Cementitious Materials:** Cementitious materials include Portland cement and flyash.

1.6.1.1 **Transportation:** When bulk cement and/or flyash is transported to the batching plant, it shall be transported within a weathertight conveyance that protects the cement and/or flyash from exposure to moisture.

1.6.1.2 **Storage:** Cementitious materials shall be stored in dry, weathertight, and properly ventilated structure(s). There shall be sufficient cementitious materials in storage at the batch plant to sustain operations for the duration of the planned placement.

1.6.2 **Aggregates:**

1.6.2.1 **Storage:** Each size of aggregate, from each source, as defined in the mixture proportioning study, shall be stored separately in free-draining stockpiles. There shall be a sufficient quantity of aggregates at the mixing plant to permit continuous uninterrupted operation for the duration of the planned placement.

1.6.2.2 **Handling:** Aggregate shall be handled in a manner to prevent segregation and breakage. Vehicles used for stockpiling or moving aggregate shall be kept clean of foreign materials. Aggregates shall be stockpiled upon a stabilized surface which precludes the possibility of introducing earth or foreign debris into the stockpile. Stockpiles found to be contaminated by earth or placed in a manner which allows segregation shall be rejected. Determination of contamination and segregation mitigation shall be accomplished by the signature delegates to the “pour agreement.”

END PART 1 - GENERAL

PART 2 - PRODUCTS AND MATERIALS

2.1 PAVEMENT QUALITY CONCRETE MIXTURES: Materials used for the concrete mixture shall include Portland cement, admixtures (chemical and/or mineral selected by the Contractor), aggregate, and water. The proportions of the mixture shall be determined by the Contractor.

2.1.1 **Portland-Cement:** Portland cement shall conform to ASTM C-150, Type _____ and shall be delivered to the site of the mixing plant in dry sealed containers. The temperature of the cement as delivered to the site of the mixing plant shall not exceed 150 degrees Fahrenheit.

****
Note: The type of cement to be used will be specified by using one of the following designations.

Type I - For general purpose use when the special properties specified for any other type are not required.

Type II - For general use and when moderate sulfate resistance or moderate heat of hydration is desired.

Type III - For use where high early strength is desired. Type III is generally not used for airfield pavement construction. It may be used for special conditions such as slab replacements on primary surfaces which cannot be closed for more than 7-day periods. The use of high cement factor concrete with Type I or II is encouraged before Type III is specified.

Type V - For use where high sulfate resistance is desired.

****
2.1.2 **Admixtures:** The use of chemical and/or mineral admixtures is the option of the Contractor subject to review and acceptance by the Contracting Officer. When admixtures are used they shall be incorporated into all mixture proportioning studies.

2.1.2.1 **Chemical Admixtures:** Admixtures shall comply with the requirements of ASTM C 260 or ASTM C 494 and shall be compatible with other mixture components. The addition of the admixtures shall not result in a chemical reaction or change in physical properties of the concrete mixture that are adverse to pavement quality concrete.

2.1.2.2 **Mineral Admixture:** Flyash may be a component when used as a mineral admixture. It shall conform to ASTM C 618, Class F or C. When flyash is used, there shall be a minimum cement content of 307 kilograms per cubic meter. The weight of flyash used in the mix shall not be less than 15 percent nor more than 2 percent when determined by dividing the weight of flyash by the combined weight of flyash and Portland cement.

2.1.3 **Aggregates:** Aggregates shall comply with the quality requirements of ASTM C-33. The grading requirements for coarse aggregates of ASTM C 33 do not apply. Aggregates shall be combined to produce an aggregate grading which satisfies the grading criteria of the approved mixture proportioning study. Crushed Portland cement concrete may be used as an aggregate when the specified quality requirements are satisfied.

2.1.3.1 **Coarse Aggregate:** Coarse aggregate is defined as that material retained on and above the Number 4 ASTM Standard Sieve (#4 sieve) size.

2.1.3.1.1 **Composition:** Coarse aggregate shall be washed and shall consist of gravel, crushed gravel, crushed stone, or a combination thereof.

2.1.3.1.2 **Quality:** Coarse aggregates, as delivered to stockpiles for use in the project, shall consist of washed clean particles which satisfy the limits for deleterious substances and physical property requirements of ASTM C-33, Table 3.

****

Note to the specifier: If the project is located within a severe weathering region, and local concrete pavements have excessive popouts, or there is D-cracking, the limits for the maximum allowable deleterious substances should be reduced to one-half of the given values in ASTM C-33. The more restrictive limits should not be used for abrasion or sulfate soundness.

****

2.1.3.1.3 **Particle Shape:** Particle shape of the coarse aggregate shall be generally rounded if gravel and cubical in shape if crushed. The quantity of flat and elongated particles in any size group shall not exceed 20 percent, by weight, as determined by CRD-C-119. A flat particle is defined as one with a ratio of width to thickness greater than three. An elongated particle is one having a ratio of length to width greater than three.

2.1.3.1.4 **Size and Grading:** The nominal maximum aggregate size shall be ______inch, Class designation ________ as defined in ASTM C-33.

****

The nominal maximum aggregate size is defined as the first sieve size less than the sieve for which 100 percent of the material may pass. The nominal maximum sieve sizes used *for airfield pavements are 37.5 millimeters, 25 millimeters, and 19 millimeters. In geographical areas where D-cracking is a known distress, the maximum size shall be 19 millimeters.*

Class designations include 1N for tropic environments, 4M for sub-tropic (moderate) environments, and 4S where there are numerous cycles of freeze-thaw and/or harsh environments where pavements are exposed to salts and severe cold temperatures. Reference ASTM C-33 for weathering zone maps.
****

2.1.4 **Blending Sizes:** Blending sizes are defined as intermediate size particles nominally passing the 9.5 millimeter sieve and retained above the ASTM Number 50 Standard Sieve (#50 sieve) size.

2.1.4.1 **Composition:** Blending sizes shall be washed clean materials of either natural deposits, manufactured products, or combinations thereof.

2.1.4.2 **Quality:** Blending sizes shall meet the limits of deleterious substances and/or physical property requirements of ASTM C 33 based upon the aggregate sizes. Material which is of the coarse material size, by definition, shall meet coarse aggregate quality requirements. The material portion which meets the definition of the fine aggregate shall meet the quality requirements of the fine aggregate.

2.1.4.3 **Particle Shape:** The particles shall be generally cubical in shape without the presence of elongated or slivered materials.

2.1.5 **Fine Aggregate:** Fine aggregate is defined as clean granular material which passes an ASTM Number 4 Standard Sieve (#4 sieve) size.

2.1.5.1 **Composition:** Fine aggregate shall be natural sand(s), or, a blend of mechanical (manufactured) sand and natural sand(s).

2.1.5.2 **Quality:** The limits for deleterious substances in the fine aggregate shall not exceed those given in ASTM C 33, Table 1.

2.1.5.3 **Grading:** The fine aggregate, as delivered to the stockpile, should be proportional to the limits of ASTM C 33 and geometrically similar to the lower limit grading curve. The maximum limitation of the fineness modulus of 3.1 specified in ASTM C-33 is not applicable and may be exceeded. The fineness moduli shall not be less than 2.3.

2.1.6 **Water:** Water for washing aggregates and for mixing concrete shall be fresh and free from injurious amounts of oils, acid, salt, alkali, organic matter, and/or other deleterious substances. The properties of the water shall exceed the minimum requirements given in CRD C-400.

2.2. MIXTURE PROPORTIONS: The concrete mixture proportions shall be determined by the Contractor QC LAB. The proportioning shall be accomplished such that workability, finish, and strength are achieved. Durability requirements will be assumed to be satisfied when the mixture is proportioned as a well graded combined aggregate and the range for air content and specified water-cement ratio are satisfied. Workability shall be judged by the Contractor giving consideration to the intended method of placement. An individual mixture proportion shall be developed for each expected method of concrete placement; i.e., slipform, fixed form, or hand placement.

2.2.1 **Composition:** Concrete composition shall be Portland cement, water, aggregates, and air entraining admixtures. Other chemical or mineral admixtures may be used at the option of the Contractor.

2.2.2 **Control of the Mixture:** The Contractor is expected to adjust the mixture proportions, as necessary, to maintain the workability depending on the construction environment. The Contracting Officer shall be informed, by the Contractor, of any changes to the mixture proportions after the performance of the test strip construction.

2.2.3 **Combined Aggregate Grading:**

2.2.3.1 **Aggregate Grading Controls :** The coarse aggregate, blending sizes (when required), and fine aggregate shall be combined to be graded from the coarse to the fine. Reports of grading shall include sieve sizes 50 millimeters, 37.5 millimeters, 25 millimeters, 19 millimeters, 12.5 millimeters, 9.5 millimeters, No.4, No. 8, No. 16, No. 30, No. 50, and No. 100.

2.2.3.2 **Percent Aggregate Retained Graph:** The combined grading shall be plotted on a graph as the percentage retained for each reporting sieve size versus the considered sieve size. The Y-axis is the percent retained. The X-axis is the sieve size. The plot of the graph should be a smooth curve showing a transition between coarse and fine aggregate. The plot shall not have a significant valley or peak between the 9.5 millimeter size and the finest reporting sieve size. Interpretation of the grading requirement and examples of the presentation is given in US Air Force publication, *Proportioning Concrete Mixtures with Graded Aggregates, A Handbook for Rigid Airfield Pavements.*

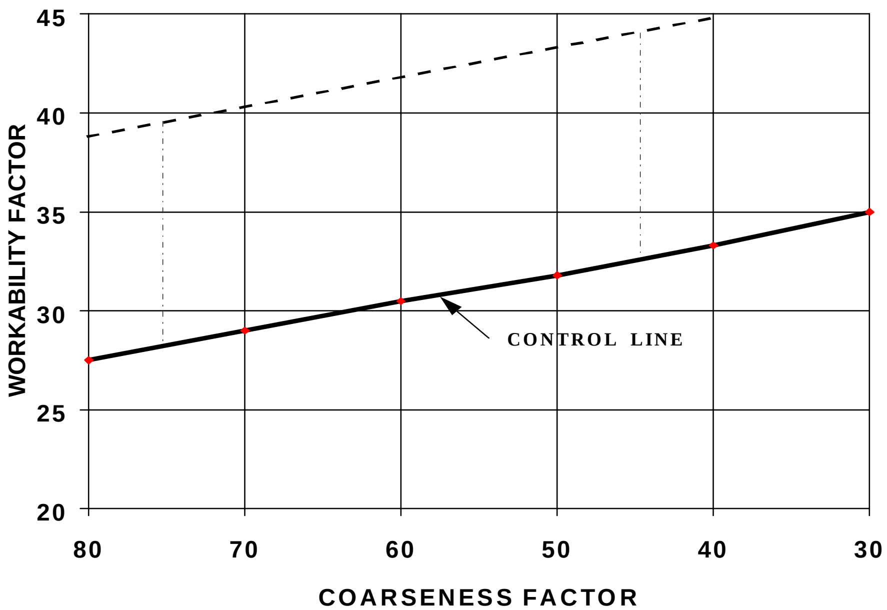
2.2.3.3 **Coarseness Factor/Workability Factor:** The combined gradation shall be used to calculate a coarseness factor and a workability factor.

2.2.3.3.1 The coarseness factor is defined as the percent of combined aggregate retained on the No. 8 sieve which is also retained on the 9.5 millimeter sieve. It is calculated by dividing the percent of material retained above the 9.5 mm sieve by the percent retained above the No. 8 sieve, times 100.

2.2.3.3.2 The workability factor is defined as the percentage of combined aggregate finer than the No. 8 sieve. The workability factor is adjusted by 2.5 units for each 43 kilograms per cubic meter of cementitious material above or below a mixture cementitious materials content of 335 kilograms per cubic meter. If the total cementitious material is 335 kilogams per cubic meter, there is no adjustment.

2.2.3.3.3 The factors, defined above, shall be plotted on a chart similar to Figure 2.2.3. The coarseness factor shall not be greater than 80 nor less than 30. The plot of the workability factor and the coarseness factor shall be a single point above the control line. The plot shall not be below the control line. The aggregate grading shall be selected to allow for a variance in the stockpile grading.

Figure 2.2.3 - Aggregate Proportioning Guide



2.2.4 **Cementitious Materials Content:** The minimum cementitious materials content shall be 335 kilograms per cubic meter of concrete.

2.2.5 **Water Cementitious Materials Ratio:** The weight of water to weight of cementitious materials ratio shall not exceed a value of 0.45.

2.2.6. **Air Content:** The air content, by volume, shall be ____________percent. The mix proportioning study shall allow for air loss, or gain, because of mixing, transporting, placement, temperature, and finishing. The air content for acceptance will be measured from concrete samples selected from in front of the paver. Appropriate adjustments for the air content at discharge from the mixer shall be included in the proportioning studies.

****
Note to the Specifier: The target air content shall be selected from Table2.2.6. The allowable variance during production is plus two and minus 1 percentage from the target. The air loss between mixer and placement should be determined at the start of production to allow for adjustment at the mixing plant.

TABLE 2.2.6 TARGET AIR CONTENT FOR CONCRETE

NOMINAL MAXIMUM AGGREGATE SIZE	SEVERE EXPOSURE	MODERATE EXPOSURE	NEGLIGIBLE EXPOSURE
37.5 mm	5 1/2	4 1/2	2 1/2
25 mm	6	4 1/2	3
19 mm	6	5	3 1/2

****
2.2.7 **Concrete Strength:** The concrete shall be proportioned for a minimum flexural strength of _____________ MPa at 90 days of age determined using the procedures of ASTM C 78. The proportioning study shall be provided in report format and will include a graph of the flexural strength versus time (in days) for the selected mixture proportions. Concrete specimens shall be tested at the ages of 7, 14, 28 and 90 days, minimum. The 90 day test criteria will be waived when the 28-day strength exceeds 90 precent of the strength specified.

****
Note to the Specifier: The designer will specify the 90-day flexural strength used for the thickness design of the pavement system. The value shall not exceed 4.5 MPa unless local pavement construction history demonstrates that higher strengths are easily achieved.
****

2.2.8 **Optional Concrete Strength Determination:** The Contractor may elect to develop a correlation between the flexural strength and the compressive strength of the concrete. If the option is selected, the compressive strength criteria may be used in lieu of flexural strength for concrete testing. The compressive strength correlation shall be developed for each mixture to be used for the work. A total of fifteen (15) sets of companion compressive cylinder specimens shall be made for the correlation from the first fifteen sets of beams cast in the field. Minimum frequency for flexural testing is described in paragraph **CONTRACTOR QUALITY CONTROL,** in Part 3 of this specification.

2.2.9 **Concrete Mixture Proportions Adjustments:** The Contractor shall adjust field batch proportions to conform to the approved mixture proportioning study and when necessary to adapt to environmental changes which vary the placement conditions.

2.3. OTHER MATERIALS:

2.3.1 **Reinforcement and Tie Bars:** All materials used for reinforcement or tie bars shall be free from loose flaky rust, loose scale, oil, grease, mud, or other deleterious materials which would reduce the bond with the concrete.

2.3.1.1 Bar mats shall conform to ASTM A 184. Welded wire fabric shall conform to ASTM A 185.

2.3.1.2 Tie bars shall be deformed steel bars conforming to ASTM A 615, A 616, or A 617 with sizes and lengths indicated on the drawings.

2.3.2 **Dowel Bars:** Dowels shall be smooth steel bars fabricated or cut to length at the shop or mill before delivery to the site. Dowels shall be free of loose flaky rust and loose scale and shall be clean and straight. Dowels may be sheared to length provided that the deformation from true shape caused by shearing does not exceed 1 millimeter on the diameter of the dowel and does not extend more than 1 millimeter from the end of the dowel. Dowels shall be epoxy coated steel bars, or painted on all surfaces with one coat of paint meeting Federal Spec TT-P-664. Dowel bars shall conform to ASTM A 615, grade 40 or 60; ASTM A 616, grade 50 or 60; or ASTM A 617, grade 40 or 60.

2.3.3 **Epoxy Resin:** All epoxy resin materials shall be two component materials conforming to the specification of ASTM C-881, Type III or Type V.

2.3.3.1 The materials used for bonding freshly mixed Portland concrete to hardened concrete shall be Type V materials.

2.3.3.2 The materials used for patching of spalls or other minor surface voids and for use for embedding dowels shall be Type III. The grade used for embedding dowels shall be Grade 3.

2.3.4 **Joint Filler for Expansion Joints:** Filler shall be preformed materials conforming to ASTM D 1751 or ASTM D 1752.

2.3.5 **Curing Materials:** Membrane forming curing compounds shall be Type 2, Class A, meeting the ASTM C 309-94 requirements.

END OF PART 2 - PRODUCTS AND MATERIALS

PART 3 - EXECUTION

3.1. PRODUCTION OF CONCRETE:

3.1.1 **Location of Plant:** The drawings will identify the location of the mixing plant, the stockpile areas, and egress when the mixing plant can be located on Government property.

****
The specifier should check to see if the plant location, access to utilities, and haul routes are clearly shown on the plans when a plant site is allowed on government property.
****

3.1.2 **Batching Plant:** The batching plant will produce a mixture which is uniform and consistent. The batching plant will have the capacity to produce a steady and consistent supply to the paver. The capacity of the batching plant shall be consistent with the placement capacity.

3.1.2.1 **Equipment:** The batching controls shall be either semiautomatic or automatic. Separate bins or compartments shall be provided for each size group of aggregate and for cementitious materials. If measured by weight, water shall not be weighed cumulatively with another ingredient, and filling and discharging valves shall be interlocked so that the discharge valve cannot be opened before the filling valve is closed. An accurate mechanical device for measuring and dispensing each admixture shall be provided.

3.1.2.2 **Scales:** Scales shall be provided for the accurate measurement and control of each of the materials in each batch of concrete. The Contractor shall provide standard test weights and any other auxiliary equipment required for checking the operating performance of each scale or other measuring device.

3.1.2.3 **Moisture Control:** The plant shall be capable of adjustment to compensate for moisture contents variations within aggregate stockpiles.

3.1.3 **Concrete Mixers:**

3.1.3.1 **General:** The mixer(s) shall not be charged in excess of the capacity recommended by the manufacturer. The mixer drum(s) shall be kept free of hardened concrete.

3.1.3.2 **Mixers:** Mixers shall be provided with an acceptable device to lock the discharge mechanism until the required mixing time has elapsed.

3.1.3.3 **Mixing Time and Uniformity:** The mixing time for each batch, after all solid materials are in the mixer, will be determined using CRD-C 55 procedures. The mixer discharge product shall meet the requirements of TABLE 3.1.3. Mixer uniformity shall be determined prior to start of concrete mixing and placement by the Contractor QC LAB.

TABLE 3.1.3 UNIFORMITY TOLERANCES IN CONCRETE MIXERS

Parameters Tested For	Maximum permissible range in results of tests and samples taken from three locations in the concrete batch.
Weight per cubic meter of mortars calculated to an air-free basis, kg per cubic meter	1.0
Air content, volume percent of concrete	1.0
Coarse aggregate content, portion by weight of each sample retained on No. 4 sieve, percent	6.0
Average compressive strength at 7 days for each sample based on average strength of all test specimens, percent	10.0
Water content, portion by weight of each sample passing No. 4 sieve, percent	1.0

3.2. **TRANSPORTING EQUIPMENT:** Concrete shall be transported to the point of discharge without segregation. Concrete may be placed directly in front of the paver by the transport vehicle provided the vehicle can traffic the base surface without causing rutting or deformation of the surface. The surface on which the pavement is being placed shall be maintained free from foreign materials and concrete that has begun to harden.

3.3. **PLACING:**

3.3.1 **General:** Concrete shall be placed within 45 minutes from the time water and cement are charged into the mixing drum. Concrete shall be deposited as close as possible to its final position. The placement of the concrete shall be uniform and continuous. Workmen with foreign material on their footwear, or construction equipment that might deposit foreign material, shall not be permitted in the placed concrete mixture.

3.3.2 **Equipment:** Mechanical pavers shall be self-propelled and shall be capable of consolidating and shaping the plastic concrete to the desired cross section in one forward pass. The paver shall finish the surface, and free edges, so that hand finishing is minimal. The paver shall have sufficient weight and power to handle the amount of concrete required for the full-lane width and depth without drag or distortion of the paver components. The paver shall be equipped with vibrators automatically controlled so that the vibrators stop as motion ceases.

3.3.3 **Spreading:** Spreading shall be by machine method except when transporting equipment is permitted on the placement surface. When placed directly in front of the paver, the concrete shall be spread evenly across the full width of the paving lane. Hand spreading will be permitted only where required for odd widths or shapes. Hand spreading shall be done with shovels; rakes are not allowed. Machines that cause displacement of forms or rut the prepared placement surface shall not be used on the project.

3.3.4 **Vibration:** Concrete shall be consolidated with mechanical vibrating equipment. The number of vibrator units and the power of each shall be adequate to properly consolidate the concrete. The vibrating unit shall be mounted on a frame with controls which allow operation at any desired depth including withdrawal. Vibrators shall not be used to spread the concrete.

3.3.5 **Placing Reinforcing Steel:**

3.3.5.1 **Pavement Thickness Greater Than 300 Millimeters:** Reinforcement steel shall be installed by pressing it into plastic concrete which has been deposited on the underlying material, consolidated, and struck to an elevation slightly higher than the design elevation of the steel reinforcement. A cover layer of concrete will be placed and consolidated within 30 minutes of the initial layer being placed.

3.3.5.2 **Pavement Thickness Less Than 300 Millimeters:** Reinforcement steel shall be positioned on suitable chairs before concrete placement.

3.3.6 **Placing During Inclement Weather:** The Contractor shall submit to the Contracting Officer a plan which describes the procedures for placement, finishing, curing, and protection of concrete during periods of inclement weather.

3.3.6.1 **Placing During Cold Weather:** Concrete placement shall be discontinued when the ambient air temperature reaches 40 degrees Fahrenheit and is falling. Placement may begin when the ambient air temperature, and the placement surface, is at 35 degrees Fahrenheit and is rising. Provision shall be made to protect the concrete from freezing during the curing period. Concrete damaged by freezing shall be removed and replaced as specified in paragraph **REMOVAL AND REPLACEMENT OF DEFECTIVE CONCRETE**.

3.3.6.2 **Placing During Hot Weather:** When the hot weather concreting procedures are likely to apply, forms and the underlying material shall be sprinkled with water immediately before placing the concrete. Concrete shall be placed at the coolest temperature practicable, but in no case shall the temperature of the concrete, when placed, exceed 90 degrees Fahrenheit.

3.4. FINISHING: Finishing operations shall be started immediately after placement of the concrete. Hand methods of finishing are permitted only on odd shapes and in the event of breakdown of the mechanical equipment. Finishing equipment and tools shall be clean and in good condition.

3.4.1 **Equipment:** The finishing machines shall operate at a continuous and uniform motion without dragging or distortion.

3.4.1.1 **Transverse Finishing:** Directly after placement, concrete shall be struck off and screeded to the crown and cross section of the design drawings. Water shall not be put on the surface of the concrete to facilitate finishing operations. Excessive manipulation that builds mortar and water on the surface are not permitted.

3.4.1.2 **Mechanical Floating:** After completion of screeding, a mechanical float may be operated to smooth and finish the pavement. The float shall be operated so as to maintain contact with the surface at all times. Components of mechanical devices which are used to float and finish the pavement surface shall have provision to disperse water and slurry buildup.

3.4.2 **Finishing After Slipform Paving:** The slipform paver shall finish the surface and the paving lane edges as the equipment maintains forward motion. The finishing equipment shall be limited to the paver screed and a float. Floating may be accomplished by hand and by mechanical bull floating. Under no circumstances shall concrete slurry be accumulated on the surface of the finished concrete nor shall concrete slurry be permitted to run down the vertical edges of the placed pavement. Concrete slurry shall not be used to build up along the edges of the concrete to compensate for excessive edge slump.

3.4.3 **Hand Finishing (Odd Shaped Slabs and Equipment Breakdown):**

3.4.3.1 **Equipment:** A straightedge and a longitudinal float shall be provided. The handle for each shall be longer than one-half the width of pavement being finished. The longitudinal float shall be at least 3 meters long, of rigid design and construction, and substantially braced as to maintain a plane surface.

3.4.3.2 **Finishing and Floating:** As soon as placed and vibrated, the concrete shall be struck off, screeded to the crown and cross section detailed, and the entire surface floated.

3.4.4 **Surface Correction and Testing:** After finishing is completed but while the concrete is still plastic, minor irregularities and score marks in the pavement surface shall be eliminated by using straightedges. Straightedges shall be 4 meters in length (minimum) and shall be operated from the sides of the pavement or from bridges. A straightedge operated from the side of the pavement shall be equipped with a handle longer than one-half the width of the pavement. The surface shall then be tested for trueness with a straightedge held in successive positions parallel and at right angles to the center line of the pavement as necessary to detect variations.

3.4.5 **Texturing:** A texture shall be applied after the surface sheen (bleed water) disappears and prior to initial set. Hand texturing using the specified devices is allowed for irregular or odd shaped slabs.

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Note to the Specifier: The specific type of texturing to be used depends on the planned use of the pavement. Specific texturing requirements should be noted on the plans. Artificial turf, burlap-drag, and broom finishing are all generally acceptable for most pavements. The Air Force requires texturing for new runways and high-speed taxiways. Subparagraphs of paragraph 3.4.5 .should be prepared from the following information to match the specific project requirements.

Burlap-Drag Texture: Surface texture shall be applied by dragging the surface of the pavement, in the direction of the concrete placement, with an approved multiple-ply burlap drag at least 3 feet in width and equal in length to the width of paving. The leading edge of the burlap shall be cleaned and changed as required. The dragging shall be done so as to produce a uniform surface texture without disfiguring marks.

Wire Comb Texture: Surface texture shall be applied using an approved wire comb. The wire comb shall be mechanically operated with the width of the comb parallel to the pavement center line. The comb shall be capable of traversing the full width of the pavement in a single pass at a uniform speed and with a uniform pressure. Texturing shall be completed before the comb mark edges will be unduly torn, but after where the serration will not close up.

Broom Texturing: Surface texture shall be applied using an approved hand or mechanical stiff bristle broom of a type that will produce uniform corrugations. For hand brooming, the brooms shall have handles longer than half the width of slab to be finished. The hand brooms shall be drawn transversely across the surface from the center line to each edge with slight overlapping strokes. For mechanical operations, the broom shall be operated with the width of the broom parallel to the pavement center line. The broom shall be capable of traversing the full width of the pavement in a single pass at a uniform speed and with a uniform pressure. Successive passes of the broom shall be overlapped the minimum necessary to obtain a uniformly textured surface. Brooms shall be washed thoroughly and dried at frequent intervals during use. Brooming should be completed before the concrete surface will be unduly torn or roughened, but after mortar will not flow and attenuate the texture.

Artificial Turf Texturing: Surface texture shall be applied by dragging the surface of the pavement in the direction of concrete placement with a full-width drag made with artificial turf. The leading transverse edge of the artificial turf drag will be securely fastened to a lightweight pole on a traveling bridge. At least 600 millimeters of the artificial turf shall be in contact with the concrete surface during dragging operations. The turf drag shall be maintained free of cement or aggregate build-up and shall not result in dislodging of aggregates from the surface.

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3.4.6 **Outlets in Pavement:** Recesses for tie-down anchors, lighting fixtures, and other outlets in the pavement shall conform to the details and dimensions given in the drawings.

3.5. <u>FORM REMOVAL</u>: Forms shall remain in place at least 12 hours after the concrete has been placed. When conditions are such that the strength gain of the concrete is delayed, the forms shall be left in place for a longer period. Forms shall be removed without injuring the concrete. Bars or heavy tools shall not be used to pry against the concrete while removing the forms.

3.6. <u>CURING</u>:

3.6.1 **General:** Concrete shall be protected against loss of moisture for at least 7 days from the time of concrete placement. Plastic concrete shall be protected from rain and flowing water.

3.6.2 **Membrane Curing:** A uniform coating of white-pigmented membrane-curing compound shall be applied to the surface of the concrete as soon as the free water (bleed water) disappears and after texturing is done. Formed surfaces shall be coated immediately after the forms are removed. Curing compound will be re-applied to concrete surfaces subjected to rainfall which occurs within 3 hours after the initial application. Concrete surfaces to which membrane-curing compounds have been applied shall be protected during the entire curing period from pedestrian and vehicular traffic except as required for joint-sawing operations and surface smoothness tests.

3.6.2.1 **Machine Application:** The curing compound shall be applied to the finished surfaces using an automatic spraying machine. The machine shall be self-propelled and shall straddle the paved lane. The machine shall have spraying nozzles that can be controlled to cover the pavement surface with a uniform application of curing compound. The drum used for supply to the spray nozzles shall be continuously agitated mechanically for the full depth of the drum during the application. Spray equipment shall have a wind guard. The curing compound shall be applied with an overlapping coverage in two coats. The total coverage shall not be more than 5 square meters per liter of curing compound.

3.6.2.2 **Hand Application:** Hand-operated pressure sprayers will be permitted only on odd widths or on concrete surfaces exposed by the removal of forms. When the application is made by hand-operated sprayers, the second coat shall be applied in a direction at right angles to the direction of the first coat

3.7. JOINTS:

3.7.1 **General:** Joints will be constructed to the details of the drawings. All joints shall be perpendicular to the finished grade of the pavement. Transverse expansion and contraction joints shall be straight and continuous from edge to edge of the pavement.

3.7.2 **Longitudinal Construction Joints:** Dowel bars shall be installed in longitudinal construction joints except where thickened edge construction and an expansion joint is required. Tie bars will be installed at locations indicated on the drawings. Dowels and tie bars shall be installed in conformance with paragraph **DOWELS AND TIE BARS,** below.

3.7.3 **Transverse Construction Joints:** Transverse construction joints shall be installed at the end of each day's placing operations and at any other location when concrete placement is interrupted for more than 45 minutes. These joints shall be located at a planned joint, except in case of equipment breakdown. When concrete placement cannot be continued, the transverse construction joint may be installed within a planned slab unit but not less than 3 meters from a planned transverse joint. Dowels shall be installed in transverse construction joints.

3.7.4 **Expansion Joints:** Expansion joints shall be formed by placing a preformed filler material at a construction joint. Expansion joints shall be formed around features that project through, into, or against the pavement.

3.7.5 **Contraction Joints:** Transverse and longitudinal contraction joints shall be of the weakened-plane or dummy type formed by sawing a groove in the hardened concrete with a power-driven saw blade. The depth of the groove formed by sawing shall be one fourth of the concrete thickness or deeper.

3.7.5.1 **Sawed Joints:** Sawed joints shall be constructed by sawing a groove in the concrete. The time of sawing shall vary but shall be done before uncontrolled shrinkage cracking occurs. Sawing of the joints shall commence as soon as the concrete has hardened sufficiently to permit cutting the concrete without chipping, spalling, or tearing. The sawed faces of joints shall be inspected for undercutting or washing of the concrete caused by early sawing. The saw cut shall not vary more than 12 millimeters from planned joint alignment. A planned joint shall not be saw cut if a crack has formed near the planned joint location. Sawing of the affected joint shall be discontinued when a crack develops ahead of the saw cut. An adequate number of sawing units shall be provided to complete the sawing before the development of shrinkage cracks.

3.7.5.2 **Protection of Sawed Joints:** Directly after sawing of joints, and before any type of traffic is allowed on the pavement surface, the sawcut joint shall be protected from moisture loss and debris intrusion. The minimum level of protection is an application of curing compound into the sawcut and continual sweeping of foreign debris. The Contractor will not allow traffic on the concrete unless measures are taken to minimize foreign materials from being introduced into sawcuts. Traffic will not be allowed on pavements for which joint protection measures have not been adopted.

3.7.5.3 **Joint Seal Reservoir.** After expiration of the minimum concrete curing period specified by the joint seal manufacturer, the upper portion of the groove shall be widened by sawing to the width and depth required for the joint seal reservoir.

3.8. **DOWELS AND TIE BARS:**

3.8.1 **Contraction Joints:** When indicated in the drawings, dowels (or tie bars) shall be placed at contraction joints during placing of the concrete. The dowels shall be welded to an assembly or held firmly by mechanical locking arrangements that prevent the dowels from rising, sliding out, or becoming distorted during paving operations. The dowel assemblies shall be held securely in the proper location by means of pins or anchors.

3.8.2 **Construction Joints:** Dowels in construction joints shall be placed in drilled holes in the hardened concrete. Holes, 3 millimeters larger in diameter than the dowels, shall be drilled with rotary-type percussion drills. Drills will be held securely in place by a jig to assure that the drill is perpendicular into the vertical face of the pavement. Dowels shall be bonded in the drilled holes by using an epoxy resin material injected into the drilled hole. The epoxy resin shall be mixed in accordance with the product manufacturer instructions. The area around dowels is to be completely filled with epoxy grout.

3.8.2.1 Dowels (or tie bars) shall be omitted when the center of a dowel will be within one slab thickness or one dowel spacing, whichever is less, from a planned joint, either contraction or construction.

3.8.2.2 Automatic dowel bar inserters, either in the plane of paving or out of plane of paving, shall be allowed only when the Contractor can demonstrate that placement of the dowel can be made without starting and stopping the paver. The inserter shall place the dowel without the need for adjustment after placement into fresh concrete. When dowels cannot be placed without adjustment, within the specified tolerances, the inserter shall not be used.

3.8.3 **Special Requirements:** The dowel end intended to be covered with fresh concrete shall be wiped clean and coated with a thin even film of lubricating oil before the concrete is placed. Dowel bars shall be installed to within 3 millimeters of alignment, for the length of the exposed dowel bar, as measured perpendicular to the face of the pavement joint. Dowel bars shall not be moved or adjusted for alignment after fresh concrete is placed and consolidated.

3.8.4 **Replacing Defective Dowel Bar(s):** A dowel bar which is placed, found to be defective, and the bonding has set, shall be cut off. A new bar shall be installed not closer than 3 but not more than 6 bar diameters from the specified bar location. When the dowels are defective for more than half of the bars in a slab length, all of the bars shall be cut off and new bars installed at half distance between placed dowels.

3.9. SEALING JOINTS: Joints shall be sealed following curing of the concrete and as soon as possible after completion of the cutting of the joint seal reservoir as weather conditions permit.

3.10. REMOVAL AND REPLACEMENT OF DEFECTIVE CONCRETE:
Defective concrete shall be removed and replaced with pavement of the thickness and quality required by this specification. Full depth saw cutting between the defective pavement and the pavement to remain is required. The removal and replacement of concrete will not result in a slab less than a full panel size (to the nearest planned longitudinal joint, when paving multiple lanes, and planned transverse joint). Defective concrete shall be removed carefully so that the adjacent pavement will not be damaged. Prior to placement of new concrete, the face of the adjacent slab shall be cleaned of debris and loose concrete. Dowel bars shall be installed as required for construction joints.

3.11. PAVEMENT PROTECTION: The Contractor shall protect the pavement from damage prior to final acceptance. Traffic shall be excluded from the pavement by erecting and maintaining barricades and signs until the concrete is at least 14 days old, or for a longer period, if so required. As a construction expedient, paving of fill-in lanes and operation of the hauling equipment will be permitted on the pavement after the pavement cures for 7 days, or strength exceeds 2.8 MPa flexural (or relevant equivalent compressive strength), and the joints are sealed or minimum levels of protection implemented. Also, the subgrade planer, concrete finishing machines, and similar equipment may be permitted to ride upon the edges of previously constructed slabs when the concrete has attained a minimum flexural strength of 2.8 MPa (or relevant equivalent compressive strength) and adequate means are furnished to prevent damage to the slab edge.

3.12. CONTRACTOR QUALITY CONTROL (QC): The Contractor shall perform the inspections and testing described. The results of these inspections and tests require that the Contractor take proactive action when the materials or the environment change. Results of testing shall be reported daily.

3.12.1 **Inspection Details and Frequency of Testing:** The number and types of testing are minimum requirements for the acceptance of the materials and the products.

3.12.1.1 **Concrete Quality Control Determination:** Concrete samples shall be obtained, using the procedures of ASTM C 172.

3.12.1.2 **Air Content**: Air content shall be determined using the procedures of ASTM C 231.

3.12.1.3 **Flexural Strength Tests**: Specimens shall be tested using the procedures in ASTM C 78.

3.12.1.4 **Compressive Strength Tests**: Specimens shall be tested using the procedures in ASTM C 39.

3.12.2 **Mixer Performance:** Before the start of concrete production the uniformity of the mixed concrete shall be determined and the mix time adjusted. Adjustments in the mixer shall be accomplished until the variation in the control parameters are within allowed limits. Mixer performance shall be validated after repair of a mechanical breakdown which affects the mixing characteristics of the plant; or when there is extreme variability in the fresh concrete.

3.12.2.1 **Scales:** The accuracy of the scales shall be determined and scales certified prior to the start of production of concrete. Scales shall also be checked when the mixture is variable in consistency and the indicated proportions do not appear to have varied from the selected proportions. Scales shall be certified after each 20,000 cubic meters of concrete mixing.

3.12.2.2 **Batch-Plant Control:** The measurement of all constituent materials of the concrete mixture shall be continuously controlled and monitored. A daily report shall be prepared by the Contractor which identifies the mixture proportions, the variance from the design mixture, and annotations where mix proportions are modified to account for variation in moisture in the aggregate, aggregate grading, and/or environmental conditions.

3.12.3 **Aggregate Testing:** The testing requirements for aggregates are dependent upon the source of stockpile development. Aggregate stockpiles developed as project dedicated sources; i.e., those developed for relocatable mixer sites -- shall be sampled and tested as the material is delivered to the stockpile. At fixed plant sites and when stockpiles are to be developed from existing stockpiles, the quantities required for the project shall be identified and stockpiled to other locations. Relocated stockpiles shall be treated as new stockpiles. Stockpiles shall be established and maintained in recognized methods for protecting the stockpile from segregation and contamination.

3.12.3.1 **Aggregate Grading:** The grading of each aggregate shall be determined as material is delivered to the project stockpiles. Grading samples shall be taken, beginning with the initial delivery, at intervals of 200 short tons for ten (10) consecutive tests. After the 10 initial tests, grading tests shall be accomplished at intervals of each 500 short tons. Sampling frequency will be increased when large deviations from the design gradation are observed. Test samples shall be taken from the stockpile.

3.12.3.1.1 **Reporting Format:** Each grading test, for each stockpile, shall be plotted on charts which report sieve sizes and the variation from the selected grading.

3.12.3.1.2 **Determination of Combined Grading:** The mathematical calculation of the combined aggregate grading, using the proportions selected for the design mixture, shall be used to determine the coarseness and workability factors. Each calculation result shall be plotted on a combined aggregate proportioning guide. Materials which have not been tested for grading shall not be placed in the mixer or incorporated into the work.

3.12.3.2 **Aggregate Moisture Content:** Moisture content of the aggregate shall be monitored by the Contractor. Additional testing and more frequent testing shall be made when the consistency of the delivered mixture is variable and the portions of aggregate and air content have not varied from the design mixture proportions.

3.12.3.2.1 **Fine Aggregate Moisture:** The fine aggregate bin shall be fitted with a moisture meter. The moisture meter shall be calibrated by gravimetric moisture determination a minimum of two times each day. One calibration test shall be at the start of each production day and the second test at the 50 percent level of the expected production for the day.

3.12.3.2.2 **Coarse and Blending Aggregate Moisture:** The coarse aggregate and the blending aggregate gravimetric moisture shall be determined a minimum of two times each day. One test shall be at the start of each production day and the second test at the 50 percent level of the expected production for the day.

3.12.4 **Concrete:** Concrete samples shall be collected by the Contractor from fresh concrete placed in front of the paver.

3.12.4.1 **Strength Tests:** A minimum of one set of test beams for flexural strength determination shall be made for each 400 cubic meters, or portion thereof, of concrete placed during each day's production. A sufficient number of specimens shall be made to allow for testing at 7 days, 14 days, 28 days, and 90 days. The Contractor shall break three beams, with the results averaged, for each test age. Beams shall be tested using the procedures of ASTM C 78. When the strength of the concrete is determined to equal or exceed the strength for the respective age of the strength gain curve of the design mix, the concrete shall be accepted for strength.

3.12.4.2. **Alternative Strength Test:** After the Contractor has done a minimum of 15 compressive strength tests and 15 flexural strength tests, the strength of the concrete may be determined with cylinders tested in compression. When the Contractor can demonstrate that compressive strength test results remain within one-standard deviation for the testing accomplished to date, all flexural strength testing may be suspended. The standard deviation does not apply to the correlation with flexural strength.

3.12.4.3 **Water - Cementitious Materials Ratio:** The Contractor shall establish a procedure to determine the relative value of the water to cementitious materials ratio. The value shall be recorded on a control chart a minimum of four times, at random, for each 400 cubic meters of fresh concrete mixed. More observations shall be made when the mixture consistency is variable.

3.12.4.3.1 **Determination of Ratio:** It is not necessary to determine the absolute value of the water content of the mixture. The sum of the gravimetric aggregate moisture and the weighed make-up water is adequate. A Troxler Model 4430, Water-Cement Gauge may be used provided that proper calibration curves are established.

3.12.4.3.2 **Interpretation of Data:** When a sufficient number of values are recorded and standard deviation units can be established, a minimum of 15 tests, limits shall be established consisting of one standard deviation and two standard deviations. When the concrete strength tests exceed the specified requirements, the entrained air content is within specification tolerance, and the water- cementitious ratio remains within one standard deviation, strength testing may be suspended.

3.12.4.4 **Air Content:** Air content shall be determined four times at random for each 400 cubic meters, or portion thereof, of concrete placed on the work. Additional tests shall be accomplished when there is variation in the workability of the concrete being placed. The results shall be plotted on a control chart with the upper limit at 2 percent above the specified value and the lower limit at 1 percent below the specified value.

3.12.5 **Placing:** The Contractor shall maintain a log recording the concrete temperature, ambient temperature, wind velocity, and humidity, on a two hour interval, during concrete production, placement, and finishing.

3.12.6 **Finished Surface:** The Contractor shall accomplish that testing which is required for grade, smoothness, and edge slump on a daily basis.

3.13 **Deficiencies Identification/Correction/Action Requirements:** The Contractor shall take the following actions when deficiencies are observed.

3.13.1 **Aggregate Grading**: The Contractor shall plot the mathematical combined gradings of the results of testing of the stockpiles. The initial point shall be established by the mixture proportioning study. The point may be relocated based upon mixture adjustments made during placement of the test strip. Based upon stockpile samples, any deviation of the point, caused by material variability, which is along a line parallel to the control line of the Aggregate Proportioning Guide, is acceptable.

3.13.1.1 **Tolerance for Aggregate Grading:** A movement of the point vertically on the Aggregate Proportioning Guide is acceptable provided that the movement does not exceed 3 units on the workability scale. The horizontal movement shall not vary by more than 5 units on the coarseness factor scale. When the variance exceeds the given tolerance, the grading shall be determined to be out of control. When proportioning can remedy the problem, adjustments to weights shall be made. When proportioning adjustments will not correct the problem, new aggregate stockpiles shall be used.

3.13.1.2 **Aggregate Stockpile Rejection: T**he combined grading, based on stockpile testing, shall not have a coarseness factor greater than 80 nor less than 30. When the combined grading shows the control variables on or below the control line, the materials used to produce the combined gradation shall be rejected and not incorporated into the work.

3.13.2 **Scales:** When the proportions are determined to be out of control, the scales shall be checked. If the scales are defective or out of calibration, the production process shall be halted and corrections made before resuming production.

3.13.3 **Concrete Quality:**

3.13.3.1 **Water-Cementitious Materials Ratio:** Strength testing shall be resumed when the water cementitious materials ratio exceeds one standard deviation, higher than the design ratio for two consecutive batches. Strength testing shall be sampled from the batch with the high standard deviation. No action is required when the deviation is below the design ratio. Concrete production shall be suspended when the water-cement ratio exceeds two standard deviations, higher than the design ratio, for two consecutive batches.

3.13.3.2 **Air Content:** When the air content approaches either the lower limit or the upper limit of the control chart, the mix proportions shall be changed. Additional testing shall be accomplished until the air content trend is steady and within the specified values. When two consecutive points are outside the air content control chart, the production of concrete shall cease until corrections can be implemented.

3.13.4 **Reports:** All results of testing, control charts, batch proportions, etc., shall be maintained in a book which shall reflect the results of all actions and is current to the preceding twenty-four hours. The Contractor shall report immediately, verbally at incidence and followed by a written notification, of the breakdown of equipment, test failure reports, or construction deficiencies.

3.14. GOVERNMENT TESTING FOR QUALITY ASSURANCE: The government will accomplish testing of the mixture when, in the opinion of the Contracting Officer representative, the combined aggregate gradations are gap graded, the aggregates are not of the same gradation as the approved mixture design, that proportions are not within the limits of the mixture design proportions, or the mixture is highly variable and not within the intent of the quality requirements of the project. The costs of the testing are paid for by the government. When the quality assurance testing reveals a failed test, the cost of the testing shall be paid for by the Contractor.

3.14.1 **Combined Aggregate Grading:** Samples shall be collected by the government from the fresh concrete mixture from in front of the paver. The sample shall be washed over a series of screens and the combined aggregate gradation determined. The resulting gradation shall be used to calculate the coarseness factor and the workability factor. Should the resulting plot be outside the design mixture variability history, or outside of defined limits, the discrepancies will be identified to the Contractor. The pour agreement shall not be executed until the discrepancies are resolved.

3.14.2 **Concrete Quality Testing:** When a combined aggregate test is accomplished, the government will perform tests for air content and strength. Samples shall be taken from the material sampled for the aggregate grading.

END OF PART 3 - EXECUTION

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